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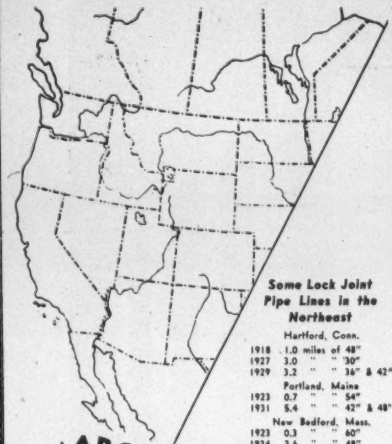

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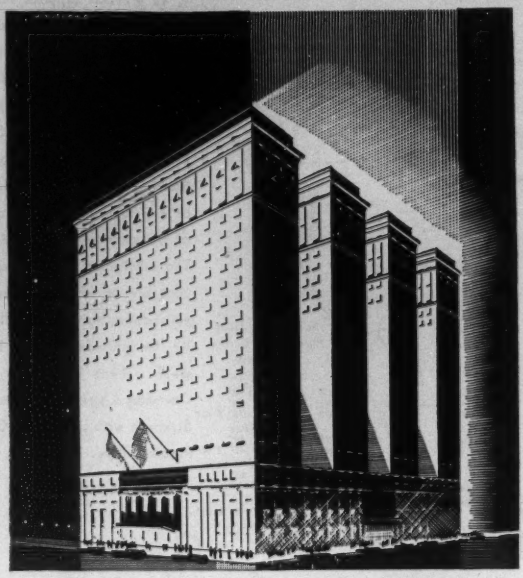

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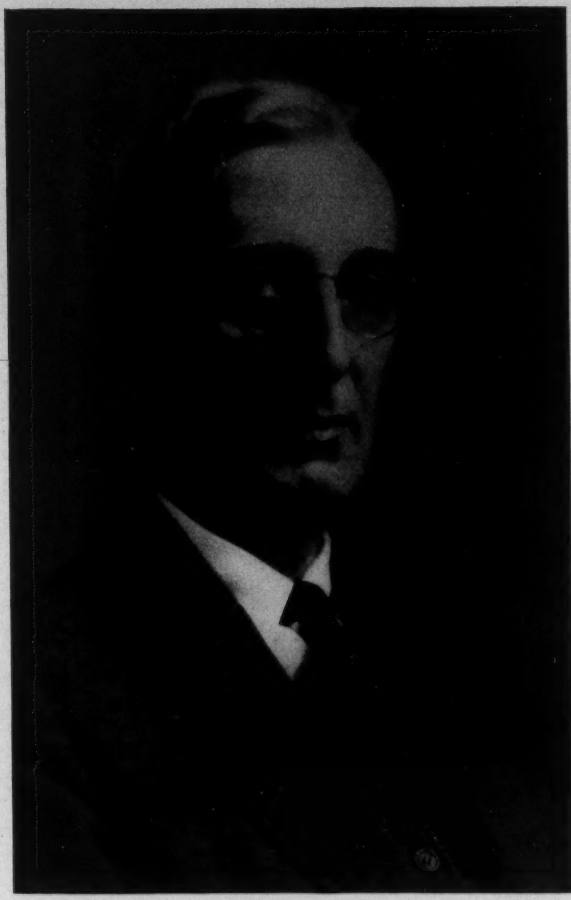

HARRY U. FULLER
President of the New England Water Works Association
1936-1937

New England Water Works Association

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FILTER BED TROUBLES AND THEIR ELIMINATION.

BY JOHN R. BAYLIS.*

[*Read September 24, 1936.*]

The rapid sand-filter bed has received considerable attention since its development about 50 years ago, though not as much as it deserves. For the past 20 or more years so much consideration has been given to other parts of the process of water purification that some may believe the condition of the filters to be of minor importance. The purpose of this paper is to urge that filter beds be kept in better condition than that in which they are now being maintained in many plants so that they will do, in a more satisfactory manner, the work expected of them. One reason for neglecting filter beds in the past has been the belief by most of those designing or operating filtration plants that sand coated with a gelatinous film is more effective than clean sand in removing bacteria and other impurities from water.

Heretofore the prevailing idea as to the best method of washing filters has been that the sand should be agitated gently rather than violently during the washing process so as not to remove all of the coating around the grains, yet to wash most of the coagulated material from the beds. Perhaps much of the reason for present methods of washing rapid sand-filters is its simplicity and cheapness. Nothing is simpler than opening a valve to let the water flow through the sand bed in the reverse direction of filtration.

That there is much trouble from filter bed clogging, pulling away from the sidewalls, and the formation of cracks at the surface, every one is aware. Occasionally there are plants where the beds remain free or almost free from such troubles, but they are not numerous. Certainly there are plants having trouble serious enough to warrant steps being taken to insure improvement in the condition of the filter beds.

This paper will be limited largely to troubles originating directly or indirectly from the coagulated material filtered from the water, and to jet

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action at the sand-gravel junction which causes ridging or displacement of the top gravel. Methods for preventing or lessening the accumulation of mud in the filters and for grading the material where the sand joins the gravel, so as to lessen the trouble caused by mixing of sand and gravel, will be given. A new method of determining the effective size of filtering material will be mentioned.

Filter Bed Troubles.

Causes. Where there is good distribution of the wash water and proper grading of the filtering materials, nearly all trouble in the filter beds may be attributed to failure of the washing system to remove from the filter all material that has been filtered from the water. The washing procedure used to decidedly the greatest extent heretofore leaves some of the material filtered from the water in the sand bed at each wash. This may accumulate to the extent that it causes an abundance of mud balls and clogged places in the bed.

Years ago when filter construction was largely in the hands of filter manufacturing companies, circular filters with mechanical rakes were used most extensively. The rakes prevented some of the clogging trouble now experienced to a considerable extent in many filtration plants. A design similar to that of the filters used years ago, however, would not be a satisfactory solution of filter bed troubles, and the added cost for the improvement obtained is not justified unless this should be the only means of obtaining any improvement whatever. A cheaper and more effective means will be given.

The effect of poor distribution of the wash water through the filter underdrains will not be discussed, except to state that lack of good distribution is a contributing cause to some of the filter bed troubles. The author would like to encourage more study of the hydraulics of filter underdrainage systems during the washing periods, for he believes that improvement can be made in obtaining more uniform distribution of the wash water than is now secured in many filters. This will prevent such troubles as can now be attributed to poor distribution of the wash water.

When a clean bed of sand is put into service to filter water that has been coagulated and settled in the usual manner and the filter is allowed to run until the loss of head reaches 8 to 9 ft. before it is washed by reversing the flow of water through the bed, it will be noted that some of the material filtered from the water cannot be removed from the filter at a rate of washing that does not wash away some of the filtering material. Part of the mud or coagulated material has become so compacted that its suspension in water is almost the same as that of the filtering material, usually sand. The specific gravity of the mud particles is considerably less than that of the sand grains, but the particles are much larger and this gives them a settling rate through water about the same as that of sand. If the particles are not broken up in some manner by an agitating force much greater than that

produced when a filter is washed by reversing the flow of water through the bed, as is the usual practice, these particles cannot be removed.

Formation of Mud Balls. Each time a filter is washed, more and more of the material filtered from the water is retained in the bed. The particles of mud become more compact. Some of them build up to larger size by more material adhering to individual particles at the surface of the bed, while in other instances several particles or mud balls come together in clumps during the washing process and are pressed together so firmly during the next filter run that they adhere to form larger masses of mud balls. Usually some sand is mixed in with the mass to give it additional weight. When a mass becomes sufficiently large and compact, it does not remain at the top of the sand. The mud balls, when newly formed, tend to rise to or near the surface when the wash water is cut off.

The mud balls become more and more compact and eventually reach a specific gravity great enough to cause them to sink to the bottom of the sand during the washing period. At the same time that they are being compacted, they are being worn away gradually by abrasion by the sand during the washing periods. Many, however, from time to time again become clumped together at certain points in the bed and some of them adhere to form larger mud balls, or mud deposits, if the clumps are formed at the bottom of the sand bed or against the sidewall of the filter. A point may be reached where the rate of wearing away is as great as the rate at which the mud balls are built up. Then the volume of the mud balls does not increase. In fact, there are many places where there are seasons of the year or conditions of the water in which the volume may decrease. The decrease is most likely to happen in the colder months.

Shrinkage of Sand Beds. A filter placed into service after being washed has an initial loss of head varying usually from 0.5 to 1.2 ft., due to friction through the bed of filtering material and the underdrainage system. The loss increases until the maximum for the filter is reached. This may be from 7 to 10 ft., or more. Nearly all of the increase in head takes place within the top 3 or 4 in. of sand, and much of it in the layer of mud filtered from the water at the sand surface. This means that there is a considerably greater force tending to press the bed downward at the high loss of head than at the beginning of the run.

When the sand grains in a filter are clean they rest directly against other grains in the bed, and unless there is some vibration of the filter there will be little settlement of the bed due to increased loss of head. Should there be a soft gelatinous coating over the sand grains, as is the case for the sand in many filtration plants, the grains will not rest directly against other grains, for there is some thickness of coating holding them apart. The coating usually is so soft that not much force is required to press the grains together a little closer, and as the loss of head increases on the filter the films give a little, allowing the grains to be pressed closer than they were when the filter was placed into service after washing.

Figure 1 shows measurements of the settling observed in a number of filter beds. A wooden cross made of boards 6 in. wide and 2 ft. long attached to a rod extending above the water surface was used for most of the measurements. Above the water line, the rod extended along side of a fixed board on a concrete sidewalk, and from time to time marks could be made on a piece of paper fastened to the rod as the loss of head increased. A smaller cross was used for some of the measurements. After the filter had been washed and was ready to be put into service the measuring device, which

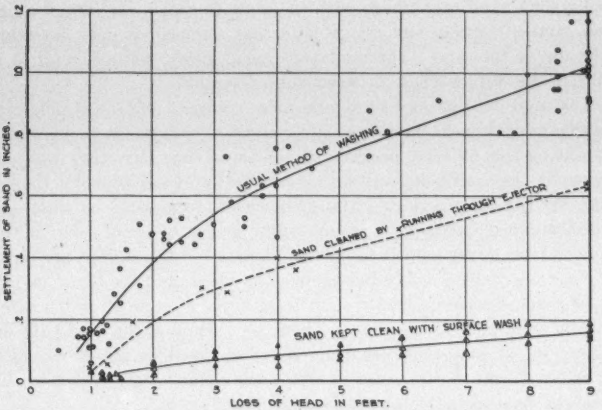
SETTLEMENT OF SAND IN INCHES.
LOSS OF HEAD IN FEET.
USUAL METHOD OF WASHING
SAND CLEANED BY RUNNING THROUGH EJECTOR
SAND KEPT CLEAN WITH SURFACE WASH

FIG. 1.—RELATION BETWEEN LOSS OF HEAD AND SETTLEMENT OF SAND IN FILTERS.

was just heavy enough to sink into the water, was lowered to the sand surface. It was pressed down slightly so as to make it come into contact with the sand over nearly all of the bottom of the cross.

The upper line in Figure 1 shows the average settlement in filters where the sand grains were coated with a fairly thick film. The middle curve shows the settlement of this same sand after it had been run through a sand ejector from one filter to another, or out of the bed and back again. All of the mud balls and a little of the coating were removed by this treatment. The settlement was reduced somewhat, but it still was much greater than it should have been. The lower line represents the settlement in a filter bed kept clean with "surface wash." It should be mentioned that the tendency of sand grains to become coated was not great in the plant where the surface wash was used, and there would not have been as much settlement as is shown by the upper lines in Figure 1. The measurements on the surface-washed filter show that if the sand grains are kept reasonably free from a coating there will be little settlement of the bed while the filter is in

service. Settlement of the beds contributes to certain filter bed troubles, for it allows beds to pull away from the sidewalls and at times permits cracks to open somewhat as shown in Figure 3.

Pulling Away from Sidewalls. There are not many filter beds that do not pull away from the sidewalls. In some plants the pulling away is little, and trouble resulting from such cause is not great. Many beds, however, pull away to the extent that this is a contributing cause to much of the clogging which develops. It is not uncommon to find filter beds that have

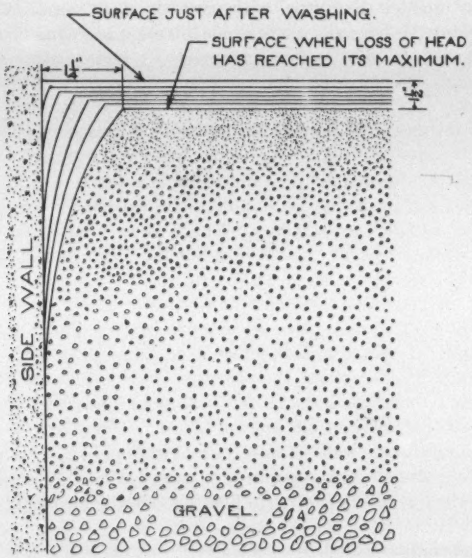

FIG. 2.— CRACKS ALONG SIDEWALLS OF FILTERS.

pulled away from the sidewall as much as one inch at the top of the bed by the time the maximum loss of head is reached. Sidewall cracks, in some instances, have been found to extend to a depth of 18 in. from the top of the bed in filters having a total sand depth of 24 in. This is three-fourths the depth of the bed. The depth of such cracks has been determined by pushing a thin sheet of iron down along the sidewall, or by digging the sand away and observing the depth to which there is side filtration. The formation of a layer of mud similar to that at the surface enables the depth of pulling away to be determined with considerable accuracy.

Figure 2, presented by the author in an article published some years ago[1], is typical of the pulling away in many filter beds. The horizontal

scale is greater than the vertical scale in order to show the pulling away more clearly. The depth to which the crack penetrates is somewhat in proportion to its width at the top of the bed. A crack ¼ in. wide at the top may extend 4 to 8 in. below the surface, but not 16 to 18 in.; likewise a crack 1 in. or more in width at the surface will extend downward more than one-half the depth of the bed.

Pulling away from the sidewalls of the filter is not something that is expected or desired. In fact it is something which should be avoided. It can take place only where there is contraction or settlement of the bed to an extent greater than usual with perfectly clean sand. Where there are cracks along the sidewalls, there is side filtration as well as filtration through the surface, and the tendency to press the bed together sideways to a point nearly as deep as the crack is about as great as the tendency to press it downward. But if the sand grains are so clean that the bed cannot be pressed downward as the loss of head on the bed increases, the bed also cannot be pressed together sideways with equal force. A small crack about ⅛ in. wide at the top, and extending downward about 2 to 4 in. below the surface is the maximum to be expected with perfectly clean sand, and the crack usually does not open up around the entire bed.

Maintenance of filter beds in a condition which will almost prevent sidewall cracks requires them to be kept much cleaner than is possible by washing the beds with backward flow of water, though a very high rate of backwash is better than a rate of 15 g.p.m. per square foot. The high rate of washing is discussed in another section of this paper. The surface wash, which also will be described in another section, appears to be the only means of keeping filter beds as clean as is necessary to prevent sidewall cracks.

Troubles Resulting from Sidewall Cracks. There are two reasons why cracks along the sidewalls of filters are objectionable: (1) A portion of the sand is by-passed, and the portion by-passed is the finer sand at the top of the bed which is most effective in filtering the water; and (2) clogged areas frequently form along the sidewalls. In observing a number of filter beds in various plants throughout the country, a large proportion of them were found to have sidewall cracks and clogged areas.

Part of Sand is By-passed through Cracks. Washing a filter stratifies partially, though not completely, the sand grains according to size. Practically all of the small grains will be found in the upper 6 in. of the bed, and nearly all of the coarsest material will be found in the lower portion of the bed. Sand having a uniformity coefficient of 1.40, according to Hazen's method of sand analysis, will have material approximately 40 per cent. greater in diameter at the middle portion of the bed than in the top 2 in. If the effective size is 0.5 mm., the sand in the middle portion of the bed will average close to 0.7 mm. in diameter. This increase in size may mean that coagulated matter will pass through the bed whereas it would not if the water passed through the finer sand.

The gradual accumulation of sediment in the clear water reservoirs of many filtration plants is proof that such matter is getting through the filters in some manner. All of this trouble cannot be attributed to cracks along the sidewalls of the filters, or to cracks within the bed somewhat as shown in Figure 3, but much of it is caused in this manner. There may be instances where such a condition constitutes a menace to health, though if not, the passage of any coagulated matter through the filter bed is objectionable and should be avoided even at considerable cost.

Clogged Areas. The formation of clogged areas along the sidewalls of filters, and occasionally in other parts of the bed, is a source of much

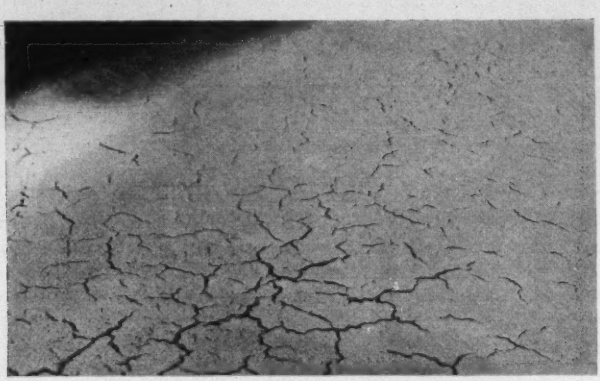

FIG. 3.— SURFACE CRACKS IN A FILTER BED.

trouble in many filtration plants. Many have regarded this as due to improper design of the washing system, and believe the trouble could be remedied if the underdrains were arranged properly. Improvement can be made, for anything which more effectively washes the sediment from the filters lessens the trouble. Nevertheless most such clogging will occur regardless of the type of underdrains used.

Figure 4 shows both typical sidewall clogging and clogging in another part of the bed. In this instance the sidewall clogged mass rests upon the gravel and does not adhere to the filter sidewall. It pulls away from the sidewall as the loss of head increases, sometimes opening a crack directly to the gravel. There is some side filtration through the clogged mass, especially in the upper part. The sand in this part usually is not badly clogged, though it is not disturbed during the washing, *i. e.*, it is not expanded like the rest of the sand. There may be a very gradual displacement of this sand. The clogged mass moves back against the sidewall during the washing period, and pulls away as the loss of head increases on the filter. Perhaps it would be more correct to say that it is pushed away, for there

is a force sideways as soon as the crack opens, and the crack probably opens a little as soon as the filter is put into service after washing.

Much study has been given to the manner in which clogged areas form. First there must be an accumulation of mud or mud balls in the filter. This almost invariably causes pulling away from the sidewalls of the filters, though it is true that there would be considerable clogging without the sidewall cracks. Certainly the pulling away aids greatly the formation of sidewall clogged areas similar to that shown in Figure 4.

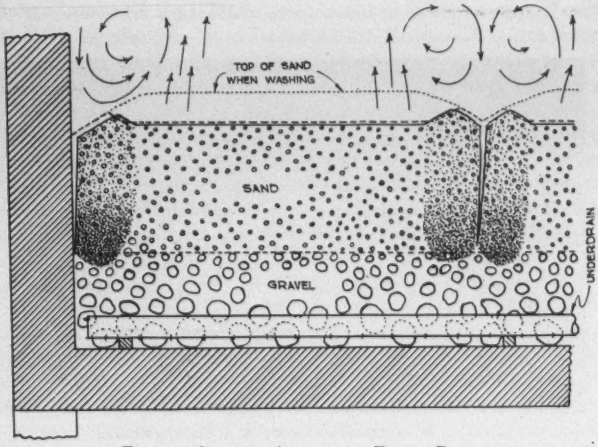

FIG. 4.— CLOGGED AREAS IN A FILTER BED.

Observations have revealed that there is a tendency for the mud balls near the surface of a filter to become clumped together during the washing process, especially where the expansion of the bed is not more than 20 to 30 per cent. No explanation can be given for the cause of this tendency to form clumps. The coming together appears to be more pronounced against the sidewall than in other parts of the bed. When a clump of mud balls, which is drifting about in the filter, moves over to the sidewall it frequently remains against the sidewall and increases in size by other mud balls drifting into the clump. The sand settles back into position after washing, and the clumps of mud balls remain against the sidewall, if they are in a position below the top of the sand when not being washed. Those above this level sink as the sand settles back, but usually remain against or near the sidewall.

Filtration tends to pack the clumps of mud balls together more firmly as the pressure on the bed increases. Some of them become packed together firmly enough to remain together during the next and succeeding washes.

Those attached to the sidewall may remain attached to the sidewall during the next wash, or they may move to another position. A clump which moves about at each wash is nothing more than a large mud ball, even though the mud balls may not be held together very firmly in the clump and frequently break up into smaller clumps or individual mud balls. Those which remain against the sidewall will almost invariably collect additional mud balls during the next and succeeding washes.

Where there is pulling away from the sidewalls, the clumps of mud balls may follow the sand and pull away also, or they may remain attached to the sidewalls. If they remain attached, the clogged places may build up from some point against the sidewall and not extend to the gravel. This is not the most common type of sidewall clogged area, for most of the masses extend to the gravel somewhat as shown in Figure 4. The illustration is typical of the clogged masses where the filter beds pull away from the sidewall. The clumps of mud balls pull away from the sidewall with the sand, but are forced back against the sidewall when the filter is washed. They may change position slightly as they grow larger and more compact—the main change being a lowering of their level in the sand each time the filter is washed until they finally become compact enough to rest upon the gravel.

Such clumps or masses of mud balls probably seldom move away from the sidewalls, whereas others drift against the sidewalls from time to time and stick there. This is one way in which the clogged places grow larger, though there is an area immediately above any large mud ball or clogged area where the sand with its included mud balls becomes much more compact than the expanded sand owing to deflection of wash water around the clogged mass. The unexpanded or only slightly expanded sand adds weight to the mass and tends to force or hold it down. The travel of the sand in the vicinity of the clogged place is such that it tends to deposit mud balls on top of the area, which enlarges the mass.

It has been stated that where there is side filtration at places pulled away from the sidewalls a layer of mud forms on the side of the bed just as it does at the surface. When the filter is shut off for washing, some of the sand, represented by the broken line in the clogged place close to the sidewall in Figure 4, breaks loose from the other sand and falls into the crack. Washing the filter tends to press the clogged mass against the sidewall, which compacts the sand and mud that has dropped down into the crack. The clogged place acts as a solid and tilts on the point that rests on the gravel. Consequently, when the mass is rocked back against the sidewall at the top, the material which has fallen down in the crack to a point several inches above the gravel causes the mass to be pried away from the wall a distance equivalent to the thickness of the new material. Hence the sidewall clogged place grows by the addition of mud and sand in the crack which is formed in each filter run, and the mass widens by being forced away from the sidewall.

The wash water probably gradually wears away some of the clogged mass, but when it is forming more rapidly than it is being worn away, the area increases. Frequently the areas reach a state where they do not increase in size, when the building up is about the same as the rate of wearing away. Many clogged places decrease in size in the winter months, indicating that the rate of wearing away is greater than the rate of building up.

Clogged Places Other than Along the Sidewalls. Large clogged places in portions of the sand bed not against the sidewalls are not of such frequent occurrence as the sidewalls clogging. The reason for this is that the tendency to form clogged places in this part of the bed is not as great as along

FIG. 5.— SAND RIDGED BY CLOGGED PLACES IN THE FILTER BED.

the sidewall. Any clogged place large enough for its presence to be indicated at the sand surface is at least several inches in diameter and rests on the gravel surface, though the absence of surface indication of clogging is not definite assurance that there is no clogging at the gravel surface. Removal of the sand from a filter frequently reveals a number of small clogged places averaging 1 to 2 or 3 in. in diameter which give no surface indication of their presence.

Figure 5 is photograph of ridged sand giving positive indication of a clogged place underneath. The clogging is several inches to a foot or more in thickness. Note the cracks, usually at or near the center of the ridged sand. Figure 4 shows a drawing of such a clogged place. The mass splits into two parts during the filtering period, and there is some side filtration through each side of the crack. The crack extends from the sand surface to the gravel, though it usually is quite small near the gravel. Each time the filter is cut off to be washed, some mud and sand break loose and fall into the crack. Then, when the filter is washed, the two parts of the mass are pressed together, widening the clogged area in the same general manner

that it is widened along the sidewall. The central clogged places of large size therefore build in width chiefly, if not entirely, from the cracks. Such cracks show plainly in Figure 5. Cracks, of course, do not start the formation of clogged places, for they originate first by the accumulation of masses of mud balls at certain points in the bed. Figure 6 shows a badly clogged filter. Such conditions are not of common occurrence, and the beds usually are cleaned in some manner before they become so badly clogged.

Washing Rate Influences Position of Mud Balls in Filters. The author has given data on the influence of the rate of washing a filter on the position of the mud balls[4]. For a mud ball to sink beneath the surface of sand, it

FIG. 6.— BADLY RIDGED SAND DUE TO EXCESSIVE CLOGGING.

must have a specific gravity greater than the sand-water mixture at the time of washing. The specific gravity of the mixture becomes less the more the bed is expanded in washing. The specific gravity may be computed by the following equation:

$$100\,S_1 = \frac{(S-1)\,(100-P)}{E} + 100$$

Here, S_1 =Specific gravity of material and water.
S =Specific gravity of filtering material.
P =Per cent porosity of the bed of material.
E =Ratio of volume of the bed to volume of the expanded bed.
(Per cent. expansion $=100\,E-100$).

If the sand grains in a filter bed are all of the same size, and there is equal expansion of the material from top to bottom, the mud balls will either remain at the surface or they will sink to the gravel layer. The variation in size causes the material in the upper part of the bed to become expanded more during washing than the material in the lower part. Consequently mud balls may be found distributed from the top to the bottom

of the sand during the washing process, when the filter contains many mud balls and some of them have become compacted sufficiently to sink to the bottom. This may be an advantage from the standpoint of preventing the mud balls from coming together to form large masses of mud balls, yet it is wrong to give preference to a non-uniform filtering material because of this alone. The washing equipment of filters should be such that the formation of mud balls is prevented, though it is known that only a few filters have adequate washing facilities at the present time.

The specific gravity of the mud in mud balls usually lies between 1.10 and 1.30. For a mud ball to sink into the sand bed during washing, it is evident that some mixture of the filtering material with the mud is essential. With mud of specific gravity 1.20, and neglecting the upward velocity of the water, the bed would have to be expanded about 4 times its original depth for the sand-water mixture to have the same specific gravity. When enough sand is mixed with the mud to give it a specific gravity of 1.60, the mud ball and sand-water mixture will have the same specific gravity at about 50 per cent. expansion of the sand.

Table 1 shows the depth to which mud balls sank into the sand of an experimental bed when the filter was washed at various rates. This is

TABLE 1.— EFFECT OF WASHING RATE ON LOCATION OF MUD BALLS IN A FILTER BED.

The filter was about 1¾ in. in diameter and contained 24 in. of sand having an effective size of 0.49 mm. The temperature of the wash water was about 9° C.

Depth of Expanded Bed Over Original Depth. Inches.	Per Cent Expansion of Sand Bed.	Rate of Wash. Gallons Per Sq. Ft. per Minute.	Lowest Depth Below Top of Expanded Bed to which any of the Mud Balls Penetrated.	
			Inches.	Per Cent Depth of Expanded Bed.
1	4.2	6.5	2	8
1.75	7.3	7.7	2.5	10
4	16.7	10.6	2.5	9
5.25	21.9	13.0	3.5	12
7	29.1	15.3	7	23
8.5	35.4	17.7	17	41
12	50.0	22.7	20	55
17	70.8	27.7	41	100

typical of a number of such tests made in glass tube filters about 1¾ in. in diameter. The penetration of the mud balls could be easily observed. The filter contained 24 in. of sand having an effective size of 0.49 mm. There were about 100 mud balls present in the filter and these ranged in size from about ⅛ to ½ in. in diameter. All of the mud balls remained close to the top of the sand until the expansion of the entire bed was about 25 per cent. Then some of them sank to lower depths as the rate of washing

was increased above this point. A washing rate which expanded the bed 71 per cent. caused some of the mud balls to sink to the gravel layer. The specific gravity of these mud balls was not determined, and as they were spread all the way from the top of the expanded sand to the gravel, they must have varied considerably in specific gravity.

Volume of Mud Balls in Filters.

If progress is to be made in keeping filter beds cleaner than heretofore, it is necessary to have some method of measuring the volume of mud

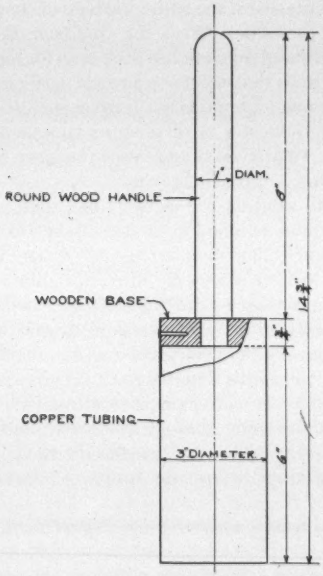

Fig. 7.—Sand Sampler.

remaining in the filters after washing. As a rule, more mud balls remain near the top of the bed than in any other part, so it would seem that if the mud balls were measured in the top 6 in. of the bed some indication of the cleanliness of the bed would be obtained. Of course, there may at times be reasons why sand from other portions of the bed should be tested, and in such cases representative samples should be collected. The procedure for measuring the mud ball volume in the top 6 in. will be given.

Procedure for Making Mud Ball Measurements. Construct a sampling tube somewhat as shown in Figure 7. The diameter of the tube is immaterial, though if it is not too large the samples may be collected more

easily. The volume of the inside of the tube we have used is such that five fillings of the tube are almost equivalent to a 6-in. cube. The filter is washed, the water drained to at least 12 in. below the surface of the sand, then the tube is pushed down 6 in. into the sand, tilted until the handle is nearly horizontal and lifted full of sand. The tilting and raising at the same time break up the sand around the place where the tube was forced down, but the sand inside the tube is not disturbed. As the sand is moist, there is no difficulty in keeping the tube full of sand without placing the hand over the end, if the diameter is not more than about 3.5 in.

Collect samples from four or more places in the bed so that the combined sample will be representative of the entire top 6 in. of the bed, placing the portions in a vessel of some kind. Wash the sand from the mud balls through a sieve. A 10-mesh standard sieve has been used for separating the sand from the mud balls. Balls that will pass through a 10-mesh sieve are not very large, and the filtering material is not large enough to be retained on such a sieve. Lower the sieve in a vessel of water to a point where the sieve is nearly submerged. Gently raise and lower the sieve about ½ in. at a time until all of the sand is washed through.

Do not place too much sand on the sieve at one time, as this may break up some of the softer mud balls and cause them to be washed through the sieve. If only a few mud balls remain on the sieve, they need not be removed before additional sand is screened. Move the mud balls to one side of the screen by tipping the sieve to an angle of 15 to 20 degrees when partly submerged and raising and lowering the sieve as well as moving it sideways a little. The downward and sideways motion should be sufficiently rapid to separate the mud balls from the sieve. With a little practice the mud balls may be moved to one side of the sieve without breaking them up. Keep adding sand and washing through the sieve until the entire sample is sieved. It may be necessary to transfer the mud balls to the measuring cylinder once or twice before the sample is sieved if a large number are present.

The volume of the mud balls is measured by displacement in cylinder graduates. Fill the graduate to the one-half mark, or to some definite mark with water. After the water has drained from the mud balls on the sieve, transfer them to the graduate. Read their volume, which is the increase in the volume of water, and compute the per cent. volume present in the sand. If, for example, the total quantity of sand and mud balls collected has a volume equal to that of a 6-in. cube (3 540 c.c.) and the volume of mud balls determined by measurement is 116 c.c., the volume of mud balls is 3.28 per cent. of that of the sample. This is not 3.28 per cent. of the total volume of sand in the filter, but of the top 6 in. The size of cylinder graduate to use will depend upon the volume of mud balls to be measured. If the volume is less than 10 c.c., a 25-c.c. or 50-c.c. graduate is satisfactory; if the volume is about 100 c.c., a 500-c.c. graduate probably is the best size to use.

Desirable Cleanliness of Filter Beds. There may be difference of opinion as to how clean a filter bed should be kept. The classification proposed in Table 2 is based upon the volume of mud balls in the top 6 in.

TABLE 2.— CLASSIFICATION OF FILTER BEDS.

Per Cent Volume of Mud Balls.	Condition of Filtering Material.
0.0 to 0.1	Excellent
0.1 to 0.2	Very good
0.2 to 0.5	Good
0.5 to 1.0	Fair
1.0 to 2.5	Fairly bad
2.5 to 5.0	Bad
Over 5.0	Very bad

The filter plant operator should strive to keep mud balls to less than 0.1 per cent. of the volume of the sand or other filtering material. This applies to the top 6 in. of the bed, assuming that no other portion of the bed will exceed this limit. Where the percentage volume of mud balls exceeds 0.2 per cent., extra facilities for washing the filters should be provided, such as the surface wash, which is described in a subsequent section of this paper.

TROUBLES AT THE SAND-GRAVEL JUNCTION.

Much of the trouble in filters originates at the sand-gravel interface or junction. This is the level where material expanded during the washing period comes in contact with material not expanded, or material in motion joins the material not in motion. The purpose of gravel in the bottom of filters is to support the filtering medium and to cover the underdrainage system so that when the wash water strikes the sand it is spread uniformly over the entire area underneath the filtering medium.

Wash water flows out of the underdrains at definite points not far apart, and the velocity at which it passes through the openings usually is high. This must be reduced to a slower velocity so that the wash water will have an approximately uniform upward momentum over the entire bed at the level where it passes from the gravel to the sand or other filtering medium. To accomplish this, gravel varying in size from large to small particles is placed in layers screened to definite sizes. A depth of 12 to 20 in. of gravel is used in many filters. The thickness varies with the type of underdrainage used and with the ideas of different individuals as to the size and thickness of gravel that should be employed.

With all the effort that has been made to produce uniform distribution of wash water in filters, there still is enough trouble that originates at the level where the gravel joins the sand to make us feel that this is a weak point in filter design. Where water passes upward from material not in motion to material partially suspended, there is bound to be jet action so that water and sand are traveling upwards at a high rate at certain points and

sand is moving downwards at other points. Unless the grading of the sand and gravel is properly designed, mixing of the two may take place; sometimes to such an extent as to make the filter inoperative.

Jet Action. As this has been described more fully by the author in another publication[5], it will be discussed only briefly. Illustration A on the left of Figure 8 shows what happens when a rapid sand-filter is washed for the first time. Instead of the sand being suspended uniformly over the gravel surface, the water and sand travel upwards over part of the area at many times the average upward velocity of the water, and the sand travels downward at other points. After taking considerable care in the design of the filters in making the gravel thick enough to kill the velocity from the openings in the underdrains, the expectation of a uniform upward velocity through the upper layers of the gravel are upset by a natural tendency to form jets of water. Doubt may arise as to the necessity of killing all of the orifice velocity where the water leaves the underdrains. The author believes it should be reduced to as uniform an upward velocity over the entire area as it is possible to obtain. Though there is no specific proof that much is gained by so doing, it is probable that anything which aids the formation of jets at certain points may also add to the natural jet-forming tendency and cause larger jets which will disturb the gravel to greater depths.

The velocity of the water in the jets is so great that it will move gravel particles several diameters larger than the sand grains that are in motion. Where the washing rate is 15 g.p.m. per square foot, the average upward velocity of the water through the gravel should be less than 0.1 ft. per sec. Tests indicate that sand having an effective size of 0.5 mm. will form jets at the sand-gravel junction with velocities close to 1.0 ft. per sec. The size of material may have some effect on the velocity of the water through the gravel and that in the jets, but for the size of sand mentioned, the jet velocity has been found to be over 10 times the average upward velocity through the area occupied by the sand.

Jet action is a natural phenomenon which will take place wherever water flows upwards through porous material with a velocity that partially suspends the material of less than a certain size. It is not confined to gravel and sand. It will be produced where fine sand overlies coarse sand and the upward velocity of the water partially suspends the fine sand but not the coarse. The size and specific gravity of the material merely affect the velocity and the size of the jets and not their formation. This statement may not apply to materials having a specific gravity not much greater than that of water, but it does apply to material likely to be used in filters.

Effect of Jet Action. Figure 8 may not portray precisely what happens at the sand-gravel junction, though it is believed to represent events closely enough to demonstrate what takes place. Parts B and C in Figure 8 show troubles produced by jet action. Gravel is moved from places where there are jets to spaces between jets. If the grading of the material from coarse

to fine is not very good, the displacement of fine gravel may be such that sand eventually will work its way down through the gravel. Where the filters are kept free from mud balls, this is about the only trouble that will develop.

When the specific gravity of the mud balls becomes great enough to cause them to settle to the bottom of the sand or other filtering material, they may be piled up in certain points by the jets, and become mashed together to the extent that they adhere and start the formation of clogged places. Filters with little or no surface indication of clogging have been found to possess an almost endless meshwork of clogged places, or pockets

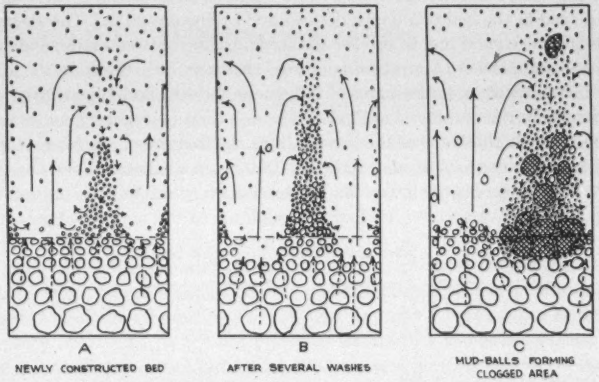

FIG. 8.— JET ACTION AT THE SAND-GRAVEL INTERFACE.

of mud, at the gravel surface. The assistance given by jet action in piling up mud balls at certain points in filters probably is responsible for most of the clogged places not along the sidewalls of filters.

The effect of jet action may not be always on the side of causing trouble, for the rapid velocity of the water in the jets may aid materially in wearing down the size of mud balls that settle to the lower part of the sand bed.

GRADING OF MATERIAL AT THE SAND-GRAVEL JUNCTION.

Experiments already published[5] indicate that a gradual transition of size from coarse to fine material is better than the grading now used in many filter beds. The grading of material for sizes over 1.0 mm. in diameter should follow approximately the equation:

$$M = K \log D$$

Where M = Depth in inches below the material 1.0 m.m. in diameter.
K = Constant.
D = Diameter of particles in millimeters.

This equation assumes theoretical grading of the material according to size. The value of K may be most any figure desired, though it is believed that it should not be greater than 14 nor less than 10. A value of 12 for K gives a very good grading of material. The depth of material of 1.0-mm. diameter and finer has to be decided upon. It is also necessary to decide upon the size at and above which material will be screened and placed in the bed by hand. A very good dividing line is believed to lie at approximately 2.0 mm. diameter. Material less than this size may be left in the sand and dependence placed upon hydraulic grading to stratify it properly in the bed, for it will be moved about during washing periods. When greater than this size, the material should be screened to sizes within certain limits and placed in the bed to a depth determined by the equation. The 10-mesh sieve is a very good one to use for the dividing line between independently screened and placed material, and material that may be included in the sand.

The kind of underdrains used influences the size and thickness of the coarsest material employed in filters. The equation just given may serve in computing the thickness of the layers above the first layer. If, for example, the first layer consists of material over 38 mm. in diameter (over 1½ in.), Table 3 gives the depths below the 1.0-mm. size for various sizes of material when K is 12.

TABLE 3.— SIZE AND DEPTH OF COARSE MATERIAL.

Diameter of Particles. Millimeters.	Depth Below 1.0-Millimeter Size. Inches.
1.0	0.0
2.0	3.6
4.0	7.2
8.0	10.8
16.0	14.4
32.0	18.1
38.0	19.0

If all material over 2.0 mm. in diameter is classified as gravel, the depth of gravel up to the 38-mm. size is 15.4 inches. Should 4.6 in. of the coarsest material be used, then the total depth of gravel would be 20.0 in.

No attempt will be made to give the size of screens which should be used. The largest particles in a screened layer of the gravel should not be more than twice the diameter of the smallest particles in that layer. There is no objection to the ratio being less, for it merely requires more screens and does not affect the total depth of the coarse material. The less the variation in screen sizes, the nearer will the material be graded according to size.

This proposed grading of materials means that more attention will have to be given to the coarse material in the sand than has been heretofore. Most of the filter sands will not contain enough of the sizes between 1.0 and 2.0 mm., and it will be necessary to supplement these with a certain amount of coarse sand. Details of how to proportion the coarse sand with the regular

filter sand have been given elsewhere[5]. One small filter in the Chicago Experimental Plant, constructed nearly in accordance with the recommended grading and washed at a rate of about 28 g.p.m. per square foot, has given no measurable displacement of the gravel in 2½ months. Considerable ridging of the gravel took place in similar filters washed at a 15-g.p.m. rate, when the transition of sizes was in accordance with usual practice — using gravel ⅛ to ¼ in. in diameter for the top layer. The higher rate should have produced a greater tendency to displace the gravel, had displacement not been resisted by better grading of the material at the sand-gravel junction level.

Cleaning Dirty Filters.

Several methods of improving the condition of filter beds have been tried with varying degrees of success. Two general procedures are used. One is to let filter beds get into bad condition and to try to clean them once, twice, or several times annually. A number of different methods have been employed: adding a strong solution of chlorine or caustic soda; raking the filters; use of a fire hose to wash the top few inches of sand; and ejection of all the sand from one bed to another, or out of the bed and back again. The other general procedure is to try to make each wash effective.

Chlorine. Chlorine solutions varying in strength up to about 50 p.p.m. of chlorine have been tried. The strong chlorine solution is kept in contact with the sand for several hours to a day or more. Some have reported success in breaking up the mud balls and in cleaning the coating from the sand grains by this procedure. The general opinion is that chlorine is not very effective in improving the condition of filter beds, or at best the improvement is only slight.

Caustic Soda. The use of caustic soda for cleaning filter beds has been practiced to a considerable extent for a long time. The amount of caustic varies from about 0.25 to 2.0 lb. or more per square foot of filter surface. Sometimes the caustic is made into a solution and then applied to the filter; in other instances it is sprinkled over the sand surface. The water in the filter is drawn down nearly to the sand surface, then caustic soda is added and mixed with two or three inches of water above the sand. The water is drawn down a little to bring the strong caustic in contact with the sand — chiefly the top several inches of the bed. The solution is allowed to stand in contact with the sand for a few hours to a day or more before being washed out. Sometimes this is followed by the use of a fire hose. Very good cleaning of the sand has been reported by this procedure. The chief objection to it is that it corrects a bad condition only to let the bed get bad again.

Raking. Considerable good has been reported by the use of rakes for breaking up clogged places. The rakes have to be used while the filter is being washed. They probably do very little good in breaking up mud balls, unless there is a tendency for mud balls of very large size to form. In-

cluded in this procedure might be mentioned the use of wire-screen baskets for dipping out the mud balls. The operators in small filtration plants may, while the filters are being washed, remove a considerable number of mud balls and keep the beds from accumulating them to an objectionable extent. Some sand will be lost in this procedure. It does not seem like a very practical method of removing the mud balls from filters.

Scraping the Surface. Scraping the surface of filters at occasional intervals has been practiced to a limited extent. The depth of material removed usually is ¼ to 1 in. of the top sand, together with such mud as is found in that part of the bed. The mud should be washed from the sand with a hose and the sand returned to the filter.

Use of Fire Hose. The operators in a number of filtration plants use hose with ½- to 1-in. nozzles to wash the surface of filter beds at occasional intervals. The water is drawn down below the sand, and the filter-to-waste valve opened so as to drain the water introduced by hosing. The strong jets of water striking the sand disturb it to a depth of several inches, and if the hose is used long enough most of the mud balls in the top few inches of sand may be broken up. Used often enough, considerable good may be accomplished, but like other procedures of this kind a bad condition is corrected merely to let it get bad again.

Ejecting the Sand. Ejecting the sand from the filter with a high pressure of water breaks up the mud balls very thoroughly in the ejected sand. In most instances the sand is shoveled into a hopper which contains the ejector at the bottom. This forces the sand and water through a hose out of the filter into a device for separating the water from the sand. A Nichols sand washer is useful for this purpose. Ejectors placed in a sand bed and used in connection with washing the filter have been tried. If the washing is continued long enough a large portion of the mud balls may be broken up in this manner. Owing to the necessity for having the wash water running during the ejecting period, this is not as good a procedure as ejecting all the sand from the filter.

Occasional Cleaning Unsatisfactory. Cleaning filter beds only after they have accumulated numerous mud balls, or have become badly clogged, cannot be regarded as good practice. Of course it has to be done to restore filters to a condition where they will give good removal of the suspended matter in the water. In most plants the beds are allowed to get into very bad condition before anything is done. The cleaning methods described are for the temporary restoration of the beds to good condition. They would be entirely too expensive for use with the frequency necessary to keep filter beds in good condition at all times. A cleansing force which will keep the beds permanently in good condition should be applied each time the filter is washed, and this is the only satisfactory procedure.

Attempts to Maintain Filters Clean.

Instead of allowing filters to become clogged, attempts have been made in some instances to use washing procedures that will keep the filters in satisfactory condition. Of the methods to be described, only one has been found successful: the use of a surface washing system.

Effect of Settling. Much may be done to lessen the tendency to form mud balls by settling most of the coagulated matter from the water. Table 4 shows the differences in the mud ball volume resulting from varying the period of settling. The results for no settling indicate how difficult it would be to keep beds handling this particular water in good condition. Very long periods of settling are not economical. Yet, if the only consideration is to avoid mud ball formation, a period of settling may be found where there would be little accumulation of mud in the filters. The author is aware of one filtration plant handling a lake water, where there is a period of settling of about 15 to 20 hours, in which very few mud balls form. With 3 to 4 hours settling, this water probably would form mud balls quite readily. A settling period of 3 to 4 hours, and the use of surface washes on the filters, no doubt would be more economical. In addition the beds would be kept in still better condition. Except for cost, there is no objection to settling the water until it is as clear as possible.

Revolving Rakes. Revolving rakes were the first extensively used adjunct to the washing process of rapid sand-filters. The author has no specific information on the effectiveness of such rakes in keeping filter beds free from mud balls. Such filters as have been observed were not free from mud balls, but such a long time has elapsed since observations have been made that it is difficult to recall the exact condition of the beds. Revolving rakes should be effective in preventing the formation of clogged areas, and they probably will prevent the formation of large mud balls. Since most of large filters are now given a rectangular plan, revolving rakes can no longer be installed. The writer does not believe it advisable to change the design of filters so that rakes may be used, especially as there is at least one other means of keeping beds in good condition.

Air and Water Wash. Use of air in connection with wash water is believed by a few to be effective in keeping filter beds in good condition. The results given in Table 5 do not indicate this. Experience in the operation of a filtration plant in which air was used also indicated that air offers very little help. In addition to this, observations on other filters where air is used strengthens the opinion that air will not prevent the formation of mud balls and clogged places. Too much reliance cannot be placed in the figures given in Table 5, for the usual amount of air was not applied. The air was supplied by a compressor which gave only about 0.4 cu. ft. per min. of air per square foot of filter surface. The air was well distributed, and some good should have been obtained with this amount of air if air wash had any merit.

TABLE 4.— EFFECT OF THE TIME OF SETTLING ON MUD BALL FORMATION.

Per Cent. of Volume of Top Six Inches of Bed Occupied by Mud Balls.

Date.	No Settling.	3.0 Hours' Settling.	6.5 Hours' Settling.
1935—Apr. 25	.00	.00	.00
May 2	2.60	.00	.00
May 9	3.79	.28	.17
May 17	4.23	.34	.23
May 23	5.65	.90	.17
May 31	8.47	1.86	.40
Jun. 6	9.35	1.84	1.08
Jun. 13	11.9	2.97	1.07
Jun. 20	11.6	...	1.47
Jun. 27	8.75	2.77	2.03
Jul. 5	13.0	3.95	2.26

Settling Time Shortened.

	No Settling.	1.8 Hours' Settling.	3.8 Hours' Settling.
1935—Jul. 11	12.4	3.67	3.38
Jul. 19	15.5	5.65	3.11
Jul. 24	13.0	5.92	2.82
Aug. 1	15.5	5.08	3.67
Aug. 8	12.7	6.49	3.39
Aug. 15	12.7	5.66	3.11
Aug. 22	15.5	5.66	2.82
Aug. 29	20.6	4.52	2.54
Sept. 5	17.5	3.95	2.83
Sept. 12	17.8	3.10	2.25
Sept. 19	20.9	4.52	2.54
Sept. 26	20.0	3.67	2.25
Oct. 3	25.1	4.52	2.83
Oct. 10	24.3	4.81	3.39
Oct. 17	24.9	5.37	3.11
Oct. 24	25.7	4.87	3.39
Oct. 31	25.5	5.08	2.49
Nov. 7	27.9	5.08	3.20
Nov. 27	24.0	6.79	5.08
Dec. 7	30.0	5.85	4.10
Dec. 12	27.9	5.66	3.95
Dec. 19	27.1	6.20	3.67

High Rates of Washing. The use of air began to be abandoned in filter design after the studies of Ellms and Gettrust[7] were published in 1916. A rate of about 15 g.p.m. per square foot became the standard for plants not using air or some other means of agitation. To see if a still higher rate of washing would improve the condition of the Baltimore filters, part of them were washed by opening the wash water valves wide and the others at about the standard rate. The author does not know the rate produced by the wide-open valve, though it must have been between 20 and 22 g.p.m. This work was done in 1922 or 1923 when the filter beds clogged badly.

The high rate of washing was continued over a period of probably two or three months. The results indicated that a higher rate of washing was not effective in lessening to a noticeable extent the formation of mud balls and clogged places.

Hulbert and Herring[8] conducted experiments at Detroit on the use of a very high rate of washing filters. They concluded that washing at a rate which gives 50 per cent. expansion of the filter bed will keep the beds in good condition. Our experience with glass tube filters washed at this rate does not indicate that it will prevent mud ball formation in filters handling Lake Michigan water, though the mud balls accumulate at a slower rate. Tests also have been made on a filter having a surface area of 10 sq. ft., with indications not much different from those of the glass tube filters. In addition to this, the high rate of washing has now been tried in a sufficient number of filtration plants throughout the country to show that it is not a cure-all for filter bed troubles resulting from the accumulation of mud in the filters. Conditions are improved materially over low rates of washing, especially rates below 15 g.p.m. per square foot (about 24 in. of vertical

TABLE 5.—VOLUME OF MUD BALLS IN FILTERS WASHED BY SEVERAL METHODS.
Per Cent. of Volume of Top Six Inches of Bed Occupied by Mud Balls.

Date.	Filter No. 2. Surface Washed.	Filter No. 5. Surface Washed.	Filter No. 6. 5 Minutes of Air, then Regular Wash at 15-g.p.m. Rate.	Filter No. 7. Regular Wash at 15-g.p.m. Rate.	Filter No. 11. High Rate 28-g.p.m. Rate.
1936					
May 28	.00	.00	.00	.00	...
Jun. 8	..	.03	.04	.08	...
Jun. 11	.06	.03	.62	.76	...
Jun. 18	.03	.00	1.33	1.89	...
Jun. 25	.04	.00	2.15	1.98	.00
Jul. 2	.00	.00	2.96	1.98	.11
Jul. 9	.00	.00	2.20	2.35	.20
Jul. 16	..	.00	2.63	2.91	.56
	Mud Balls Cleaned From All Filters July 17, 1936.				
1936					
Jul. 23	.00	.00	*.28	.14	.03
Jul. 30	.00	.00	.93	.71	.11
Aug. 5	.00	.00	1.33	1.35	.23
Aug. 14	.00	.00	1.55	1.61	.17
Aug. 20	.00	.00	1.55	1.98	.88
Aug. 27	.00	.00	2.09	2.68	1.47
Sept. 3	.03	.00	3.53	3.10	3.67
Sept. 15	.03	.00	3.13	3.96	3.13

* After July 17, air and water were used together for a period of 5 minutes. The rate of washing was about 8 g.p.m. per square foot. This was followed by washing for one minute at a 15-g.p.m. rate without the use of air.

rise per minute); and if nothing else could be done, a high rate of washing would have to be used providing it could be used without the loss of sand. This statement also assumes that the underdrainage system and the grading of the gravel can be perfected to the point where there will be no serious displacement of the gravel. Ridging of the gravel, as has been shown, is a frequent trouble in filter beds, and a high rate of washing may make it more pronounced.

Table 5 gives comparisons of filters washed by several methods. Probably the slowness with which the volume of mud balls increased in the filter washed at the highest rate cannot be attributed entirely to the high rate of washing, for it was a newly constructed bed. Large mud balls did not form readily, and the bed maintained the appearance of being in good condition. The improved condition is believed to be due to the high expansion of the sand preventing, to a considerable extent, the coming together of mud balls to form larger ones.

In making mud ball measurements on the filter washed at 28-g.p.m. rate, it was noticed that the mud balls were nearly all less than ¼ in. in diameter, whereas for the filter washed at 15-g.p.m. rate some of the mud balls were more than ½ in. in diameter. Another interesting point in connection with the measurements was that if the wash water was cut off within about 10 seconds the percentage of mud balls in the top 6 in. was considerably less than if it was cut off slowly. The explanation for this probably is that the mud balls were distributed more evenly throughout the sand bed instead of being largely at the top of the bed.

In a filtration plant recently put into service, the volume of mud balls increased to about 3.7 per cent. of the top 6 in. of material within about one month. The filters were washed at a rate of 20 to 22 g.p.m. per square foot giving about 27 per cent. expansion of the beds. This plant was designed for a still higher rate, but there was loss of sand when the rate was increased above about 21 g.p.m.

High Rate of Washing and Sand Loss. Application of the high rate of wash is not as simple as some may believe it to be. Some of the plants designed to use a high rate of washing have not been able to do so on account of the loss of sand. These designs have been made apparently with the assumption that if the general level of the top of the expanded sand is about 12 to 15 in. below the top of the wash-water troughs there would be no loss of sand. This has not been the case, for in some instances sand has been thrown as high as 20 in. or more into the wash water troughs at rates of washing considerably less than necessary to produce 50 per cent. expansion of the bed. In the plant to which reference has been made, there was a distance of about 29 in. from the top of the unexpanded bed to the top of the wash-water troughs. The depth of the beds was about 30 in.

The reason why sand may be thrown so high up into the water at certain points may be explained by Figure 9. Considerable velocity is

imparted to some of the water coming from underneath the wash water troughs where the troughs extend below the top of the expanded bed, and the wider the troughs, the greater is the amount of water which must escape around the troughs. Very high rates of washing require larger troughs to take away the wash water, and the tendency in design is to make the troughs both wider and deeper. The distance from the top of the beds to the top of the troughs has, in some instances, been increased, though not enough to prevent loss of sand at very high washing rates. Consequently, when the filter is washed, part of the underside of the troughs may be several inches

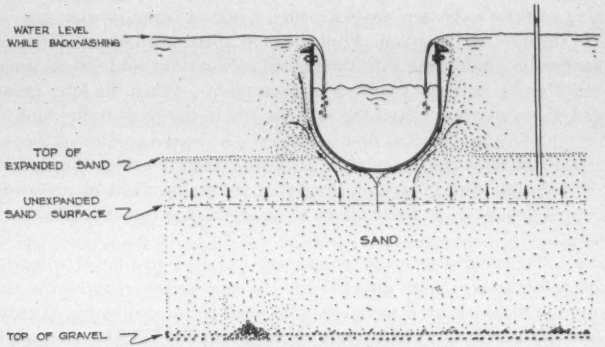

FIG. 9.— CROSS-SECTION THROUGH FILTER SHOWING LOSS OF SAND DURING BACKWASHING.

below the top of the expanded sand. It does not seem desirable to raise the wash water troughs much more than 30 in. above the sand.

If a glass tube is placed in a filter in a vertical position so that the bottom extends 4 in. into the expanded sand and the top a few inches above the water surface of the filter, the water will rise in the tube about 2.5 in. above the top of the water on the filter if the expansion of the sand in this part of the bed is about 50 per cent. Water 4 in. below the top of the expanded sand, without any sand included in it, would have a tendency to flow into the water above the sand equal to that produced by a head of 2.4 in. of water (nearly 3.5 ft. per sec.). Probably all of this head cannot be converted into velocity, and there will be some sand included, yet it is believed possible for the velocity to exceed 2 ft. per sec. This momentum, when imparted to a sufficient volume of water, may not be checked sufficiently to allow the sand to drop out before the water is thrown up to a level of the wash water troughs.

The settling velocity in water of sand 0.5 mm. in diameter is close to 0.2 ft. per sec. If, therefore the velocity of about 2 ft. per sec. is not reduced to less than about 0.2 ft. per sec. by the time it reaches the top of the wash-

water troughs, sand will be thrown over. With other factors tending to aid the upward velocity rather than retard it, such as the general flow of the water upwards, and the movement towards the weir as the water overflows the trough, it is easy to see how the sand may be thrust upwards a considerable distance. Thus it is seen that the use of very high washing rates involves more than merely increasing the amount of water applied underneath the filter beds.

The Surface Wash.

Early Uses of Surface Washes. For fear that some may believe surface washing systems to be new developments, a brief account of what has been done in the past will be given. Prior to about 1880, small filters which were not scraped in accordance with the procedure for slow sand filters, usually had the filtering material confined between plates. When the filter became clogged, the water was forced through the bed in the reverse direction. A high rate of flow was used at first to wash out at least a portion of the sediment removed from the water, then, if desired, the filter might be operated in this direction until it became clogged or the water could be reversed to its original direction. In these filters, the material was not expanded during washing.

Probably the first attempt to get away from this method of constructing filters was to try sprays directed into the sand bed from above the sand. The sand in these beds was not packed between perforated plates. A patent was granted in 1881 to Patrick Clark (U. S. Patent No. 243 212) on a process of cleaning filter beds composed of sand or other granular materials, in which the apparatus consisted of a revolving hollow arm or pipe above the filter surface having apertures on the lower side and actuated horizontally by means of internal hydraulic pressure. No mention was made of using a backward flow of water to assist in driving the muddy water away, though this may have been intended.

Hyatt in 1881, was granted a patent (U. S. Patent No. 243 265) on a filter which had a washing or agitating system located in the bed near the surface of the filtering material. The washer pipes containing apertures were covered with wire cloth to prevent the sand from getting into the pipes. The system was rotated by hand during the washing period to cleanse the material thoroughly. The filter beds could also be washed by reversing the flow of water through the beds, and either or both systems of washing could be used. In another patent granted to Hyatt (U. S. Patent No. 248 468) a few months later, it was stated that: "The filter bed may be cleansed by reversing the flow current of water through the apparatus, either alone or in connection with the operation of the washer pipe . . . ."

Shortly after this, the rapid sand-filter constructed along lines later used extensively was developed. Almost simultaneously with this development came the mechanical rake to assist the backwashing in removing the mud from the filter. This took the place of the surface washing systems,

and no further mention of surface washing is found until 1908, when DeBerard and Pearse[9] experimented with a surface washing system in one of the experimental filters at Oakland, California. Full details of the system were not given, though the plan showed seven pipe laterals connected to a header at one side of the filter. The filter was 4 ft. square.

Amsbary[10] has described the surface washing system of the Champaign and Urbana Water Co., constructed about 1914 or 1915. He states that during July, 1914, an experimental grid was placed in one of the filters, and that after six months' trial the effectiveness of the grid was so evident that similar grids were placed in all the filters. The piping system consisted of 2 parallel manifolds made up of 4-in. nipples 15 in. long and 4- by ¾-in. crosses. The laterals were perforated on the under surface at 12-in. intervals, first with 1/16-in., then ⅛-in, and finally 3/16-in. holes. The surface washing system at Urbana was later abandoned, for Babbitt[11], in 1924, states that although they were partly successful, the amount of water required for the jets was so great as to render their use uneconomical.

The author[1], in 1924, described experiments with surface washing at Baltimore. The system was located in a section of one of the large filters. At first, ⅛-in. holes were located 12 in. apart on each side of the ¾-in. pipe laterals spaced 12 in. apart. The holes projected the jets horizontally. This gave two ⅛-in. openings for each square foot of filtering surface. The laterals were first located in the sand beds above 2 or 3 in. below the surface, then about 2 in. above the top of the sand. Later this was changed to laterals with 3/16-in. holes projecting the jets downward at an angle of about 30 degrees to the horizontal. The pressure used was 35 to 40 lb. per sq. in. A section of another filter was equipped with laterals located nearly 24 in. apart, and having 3/16-in. holes throwing the jets downward at about 30 degrees. These surface washing systems appeared to be successful in keeping the sand in good condition in the sections in which they were located. The experiments at Baltimore, however, did not attract enough attention to start the installation of surface washing systems at other filtration plants. The operator of a privately owned water plant informed the writer a year or so afterwards that he installed surface washing systems in the filters of his plant, and that they worked satisfactorily.

When the Chicago Experimental Filtration Plant was constructed in 1927, all filters were equipped with surface washing systems. Alternate use and non-use of these systems has enabled us to collect considerable information on the effectiveness of this system of washing filters. Experiments on various methods of washing filters at Chicago have been described by Hudson[12].

The Surface Washing Systems in the Chicago Experimental Plant. The surface washing system originally installed in the larger filters which have 100 sq. ft. of filtering surface (10 ft. by 10 ft.) consisted of a 2½-in. pipe leading to a header across the center of the filter. The ¾-in. laterals were spaced 20 in. apart, and contained 3/16-in. holes 12 in. on both sides of the

pipes, pointed downward at an angle of about 30 degrees to the horizontal. There were six laterals and 96 holes for the 100 sq. ft. of filtering surface. The circular filters, having 10 sq. ft. each of filtering surface, had a one-inch pipe across the center with six 3/16-in. holes. The laterals were suspended from 2 to 4 in. above the top of the sand. These systems worked all right, but there was some clogging of the openings and a gradual wear on the holes. After three to four years' use of the systems, some of the holes had areas nearly twice the original. It is thought that this wear was due largely to corrosion of the surface which was kept scoured clean by the

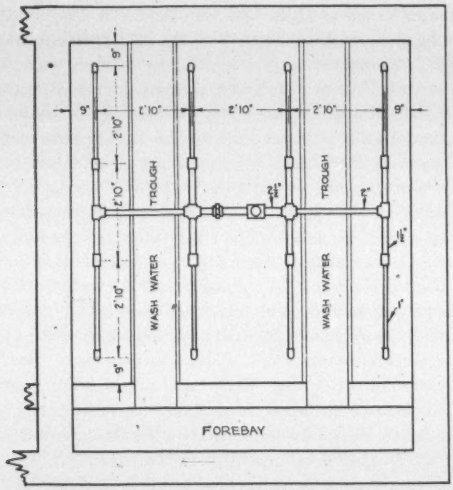

FIG. 10.—PLAN OF SURFACE-WASH PIPING IN PLANT FILTER.

sand during washing. To lessen the wear and to decrease the clogging trouble, a new design for the surface washing system of one of the larger filters was developed.

New Design for Surface Washing System. Figures 10 and 11 show details of the new surface washing system installed in 1935 in one of the larger filters. The laterals are located above the wash water troughs, and have 1-in. down-pipes extending nearly to the sand. There are 16 of these down-pipes spaced 34 in. apart each way for the 100 sq. ft. of filtering surface. Brass caps with five ¼-in. holes are fastened to the ends of the pipes. Four of the holes project jets of water downward at an angle of about 38 degrees to the horizontal, and the fifth is pointed straight downward. With a pressure head of 10 feet of water on the down-pipes, the surface washing system gives 2.1 g.p.m. per square foot; and when the

pressure is 20 ft., the flow is 3.1 g.p.m. Figure 12 is a photograph of the jets turned on when the water was drained below the sand in the filter.

After being in service for more than a year, there is no sign of wear on the holes. The only clogging has been due to substances in the raw water,

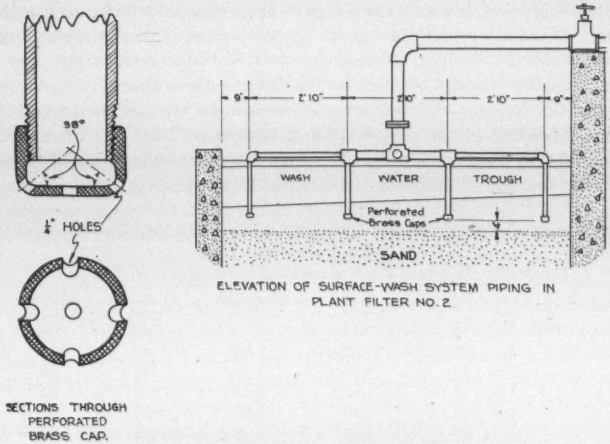

FIG. 11.— DETAILS OF SURFACE-WASH PIPING.

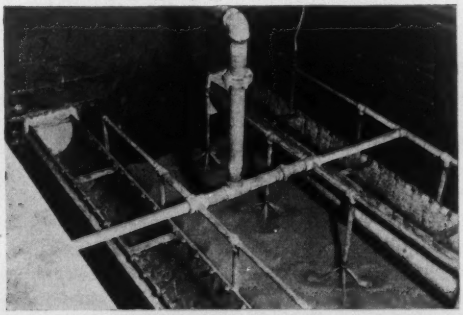

FIG. 12.— SURFACE WASHING SYSTEM WITH JETS TURNED ON.

which is used for the washing system. Occasionally a hole has been found clogged with a small fish, snail shell, or rust tubercle.

The piping system has been raised and lowered to find the point where best washing is obtained. Best results were obtained with the caps on the ends of the pipes located about 4 in. above the sand when the filter is not

being washed. When the bed is expanded 2 to 3 in. by the regular backwash, the jets strike with their greatest force in the part of the sand containing the largest number of mud balls.

Results Obtained. Tables 5 and 6 show that the new system is effective in keeping mud balls down to a point where there are almost none. This has been done with a water pressure of approximately 19 ft. on the down-pipes. In addition, the spacing of the down-pipes is further apart than is recommended. Washing with a head of 11 to 12 ft. on the down-pipes left a measurable amount of mud in the filter — the volume being between 0.2 and 0.4 per cent. of the volume of sand in the top 6 in. of the bed. The filter, according to the classification proposed in Table 2, still would be considered in good condition, yet the volume was higher than is believed essential to avoid entirely the formation of clogged places.

TABLE 6.— EFFECT OF THE TIME OF SETTLING AND SURFACE WASHING ON MUD BALL FORMATION.

Per Cent. of Volume of Top Six Inches of Bed Occupied by Mud Balls.

Date.	No Settling.	1.8 Hours' Settling.	3.8 Hours' Settling.	Filter Surface Washed.
1936—Jan. 9	.13	.58	.03	.03
Jan. 16	.42	.80	.51	.00
Jan. 29	1.55	1.19	.57	.00
Feb. 4	1.83	1.55	1.27	.00
Feb. 13	2.26	2.26	.76	.00
Feb. 19	1.98	2.12	.91	.00
Feb. 26	2.66	3.08	1.50	.00
Mar. 5	2.88	3.06	1.19	.00
Mar. 27	4.81	4.66	2.46	.01
Apr. 2	4.59	2.83	2.12	.00
Apr. 9	4.72	5.74	2.15	.00
Apr. 15	3.37	5.94	1.90	.00
Apr. 24	6.50	7.77	2.72	.06
Apr. 30	6.22	6.14	4.95	.08
May 7	10.4	7.50	3.39	.05
May 14	10.6	9.90	4.67	..
May 21	13.6	12.3	3.82	.10
May 27	21.0	10.4	4.24	.11

The new system was purposely made less extensive than was thought necessary for a filter handling Lake Michigan water with the treatment being given the water. But with 19 ft. head on the down-pipes it has kept the mud balls broken up satisfactorily. For fear that there will be times when the tendency to clog is greater than it has been during the period of test, a more extensive system than that shown in Figures 10 and 11 is recommended for the type of water on which the tests were conducted.

Procedure for Washing Filter. The procedure employed for washing the filter with the new surface washing system is believed to be typical of what should be used on any filter. When the filter was ready to be washed, the water was drawn down to within a few inches of the sand. The surface

washing system valve was opened to the desired point, then the washwater valve for the backwash was opened enough to give about 10 per cent. expansion of the bed, which for the size sand used, was about 10 g.p.m. per square foot or about 16 in. rise per minute. For filter runs not in excess of 24 hours, the washing through the underneath wash was continued at the 10-g.p.m. rate for two minutes, then it was increased to about 14 g.p.m. for one minute.

One-half minute after starting to open the wash-water valve to increase the backwash, closing the surface-wash valve was started. Closing the backwash valve was started 3 minutes after being opened to the 10-g.p.m. rate. This gave approximately two minutes of the underneath wash at the 10-g.p.m. rate and nearly one minute at the 14-g.p.m. rate. The surface wash valve was open for about 3 minutes. The purpose of increasing the washing rate near the end of the wash was to expand the entire bed of sand, and to wash more thoroughly the muddy water from the filter. Ten per cent. expansion of a bed of sand may not place all of the lower portion of the bed in motion.

The mud balls remain nearer the surface with a slight expansion of the sand bed than when there is considerable expansion. Also the mud balls coming within the force of the jets are thrown more violently against the sand when it is not greatly expanded. The sand must be fluid in the upper part of the bed so that the mud balls will be drawn into the paths of the jets, but it should be expanded as little as possible above the point of making it fluid.

Suggestions for the Design of Surface Washing Systems.

Complete designing details will not be given. There are a few filtration plants where the filter beds keep in such good condition that surface washing is unnecessary. Assuming that there is a good backwashing system in the filters, the maximum amount of water that need be used in beds filtering water with a very great tendency to clog is about 7 to 8 g.p.m. per square foot. Any system installed where the tendency to form mud balls is slight should be capable of supplying at least 2 g.p.m. of water to each square foot. It is probably more economical to use high pressure on the jets where the tendency to form mud balls and clogged areas is great than to use low pressure. Local conditions will govern the pressure to be used. In general, the pressure at the jets should be at least equivalent to 20 ft. of water, and a head of 50 or 60 ft. is better for filters which readily form mud balls. Where the water for the surface washing system is taken from the high-pressure line, the full pressure may be used. If the pressure is more than about 50 ft. at the jets, fewer jets or smaller openings may be employed.

When five ¼-in. holes are used for each cap on a down-pipe, 1-in. pipe should be employed for the down-pipes. The size of the pipes from the line feeding the system to the down-pipe should be such that there is not

too much friction loss. The spacing of the down-pipes should be between 24 and 30 in. each way when 4 to 8 g.p.m. of water are needed for each square foot of filtering surface. Where it is known that 2 to 3 g.p.m. are sufficient, the spacing may be from 30 to 36 in. apart. The author[4] has illustrated a design which is thought to be satisfactory for large filter beds. This design shows a 16-in. pipe feeding the surface washing system of a filter having about 1 400 sq. ft. of filtering surface. There may be few cases where such a large feeder line is necessary, yet it is better to err on the side of providing too much water than not enough.

Surface washing systems that have been installed, of which the writer is aware, have pipe laterals near the sand surface somewhat similar to the design first used at the Chicago Experimental Plant, or in the Baltimore experiments. If sufficient water is provided under a head which imparts considerable velocity to the jets, satisfactory results may be obtained. It is believed that more trouble will be experienced with the older design, and while it may be a little cheaper to install with galvanized iron pipe, replacement of the pipe owing to gradual enlargement of the holes will soon offset the difference in first cost. Brass pipe could be substituted for galvanized iron, and this may be cheaper than more frequent replacement of iron pipe. Regardless of the system used, it is important that an adequate surface washing system be installed for it is to play an important part in maintaining the filters in good working order.

Advantages of the Surface Wash.

The advantages of surface wash are synonymous with those of a clean filter bed, for a properly designed surface washing system will prevent mud ball formation, cracks, and clogged places in the filter beds. No other method has been developed which will keep the filter beds as clean as it is possible to keep them with jets of water properly distributed and under considerable pressure when thrown into the top of the slightly expanded bed. The character of the water and the treatment given it influence the amount and pressure of water that should be used, but there is some rate and pressure of water which will effectively break up the mud filtered from the water so that it may easily be washed from the filters.

What difference does it make if the filters are dirty? Aside from esthetic considerations there are very definite practical reasons for keeping filter beds as clean as possible. A better water can be produced by a clean filter than by a dirty one. In some cases surface wash may be cheaper than the present cleaning programs. And there are cases where clean filters give longer filter runs than dirty ones.

Operators of filtration plants are employed to improve the quality of the water, hence they should be most interested in operating methods which will help them in that mission. A filter that is allowed to form cracks, allows water to by-pass the fine sand at the top of the filter, thus giving the

turbidity opportunity to pass through the filter. Clogged places in filter beds are sometimes so extensive as to appreciably increase the rate of filtration through the unclogged portions. Chicago experiments have shown that filters operated at high rates of filtration sometimes permit the turbidity to be forced through the sand.

Mud balls form at the top surface of the sand in rapid filters, at the point where the fine sand which does the major portion of the filtration is situated. Entrapment of the fine sand in the mud balls and eventually in the clogged masses leaves only the coarser sand to do the work of filtering. Sometimes preventable coatings form around the sand grains, and when these coatings are hard and not very compressible, they increase the effective size of the sand. When this can take place, it is useless to select carefully sized sand.

Clogged places cause disruption of the gravel layer, sometimes making it very uneven, at times forcing the gravel up to points close to the top of the sand, thus reducing the depth of sand through which effective filtration takes place. With gravel so seriously disturbed, it is nothing unusual to find sand in the clear well. Most serious of troubles of this kind, however, is that which occurs when the gravel layer is forced clear through the sand layer by clogged masses, thus rendering the filter inoperative. Accompanying these gravel derangement troubles, is the problem of underdrains which become clogged with sand, thus necessitating rebuilding of the entire filter bed.

The rapid sand-filter is a vital step in the usual process of water purification, and it should not be allowed to become so fouled that it fails to do its job. There are many cases where bacteria have grown in filter beds to such an extent that there were more bacteria in the filter effluent than in the influent. Such growths should be few or entirely absent in a clean bed. It is a common occurrence to see large absorption of chlorine in filter beds where the water is prechlorinated, and the least that may be said is that this is wasteful of chlorine. Only a slight exercise of the imagination is needed to visualize what happens to the odor threshold of water that passes through a filter that is laden with a year's collection of coagulated matter.

In still other cases, soft, pliable, gelatinous coatings may form around the sand grains. These coatings are compressible, and when the head of filtration presses on the sand, they are squeezed until the void spaces are very small indeed. This leads to excessively short filter runs.

Surface washing systems can be installed in practically all existing filters, and at a cost that is not great. After installation, the cost of keeping the filters in good condition will be very little more, and in many cases, less, than the cost of the present system of washing which does not keep them in good condition. The amount of wash water now being applied beneath the beds may, in many instances, be reduced. For some plants the reduction will exceed the amount which needs to be applied through the surface washing system.

Hudson[12] has shown that surface washed filters are more effective in filtering the coagulated matter from the water during periods when the coagulated matter penetrates deeply into the filter beds. Such bacterial information as is available indicates no reduction in the bacterial efficiency of the filters resulting from keeping the beds clean.

More money is now being spent in some filtration plants within a period of a few years trying to restore the filters to good condition than the cost of installing an effective washing system. Not only this, but the filters in these and many other plants are being operated at reduced efficiency most of the time.

The advantages of keeping filter beds in good condition seem so obvious that no one should hesitate to do so. In fact, the operator who does not maintain his filters in good condition soon will be regarded as negligent in the operation of his plant.

Effective Size of Filtering Material.

Too much space would be required to go into details about the author's method for determining an effective size of filtering materials, and as it has been published already[2] only brief mention will be made. The author's method takes as the effective size the average of the 1, 2, 4, 8, 16, and 32 per cent. sizes. In stating a certain per cent. size, it means that this per cent. of the material by weight is of the size and smaller in diameter. No material is considered in the average which is more than 1.5 times greater in diameter than the 1 per cent. size.

The uniformity coefficient is taken as the per cent. of the material by weight of a size 1.5 times the diameter of the 1 per cent. size. Perhaps "size range" would be a better term than "uniformity coefficient."

The author's method gives an effective size close to that obtained by the Hazen method where the sand is about as uniform in size as is practical to obtain from beds of sand extensively used for filter sand. The results may vary considerably from the size determined by the Hazen method where the material is not so uniform in size. The clogging rate has a certain definite relation to the size when determined by the author's method, whereas it does not by the Hazen effective size. The lengths of filter runs have been found to vary approximately as the 2.15 power of the diameter of the effective size as determined by the author's method.

Summary.

Filter bed troubles resulting from accumulating in the beds the compacted coagulated material filtered from the water are discussed. Where there is good distribution of the wash water underneath the beds, nearly all filter bed trouble may be attributed to this accumulation of mud.

Shrinkage or settlement of the filter beds as the filter continues in service is due to a soft coating around the sand grains. The shrinkage

allows cracks to open along the sidewalls, and sometimes in other parts of the bed. This allows some of the water to by-pass the finer sand at the surface of the bed.

Clogged areas frequently form along the sidewalls of filters, and when they become very large, cracks may open along the sidewall which extend down to, or nearly to the gravel.

Clogged areas sometime form in other parts of the bed where the tendency of the water to form mud balls is great. These clogged areas start by mud balls accumulating at certain points on top of the gravel. Large clogged areas in the center of the beds also may open up cracks down to, or nearly to the gravel.

The higher the rate of washing, the deeper the mud balls sink into the sand during washing, but they do not have so great a tendency to come together to form masses of mud balls at high rates of washing.

A procedure for measuring the volume of mud balls in filters is given. Mud balls may, within a period of several months, accumulate in beds washed at a rate of about 15 g.p.m. per square foot to the extent that 3 to 5 per cent. of the volume of the sand in the top 6 in. of the bed consists of mud balls. A less amount of mud usually will be found where rates of washing higher than this are used, and more will be found where the rates of washing are lower.

The amount of coagulated matter going to the filters influences the rate of mud ball formation. Long periods of settling lessen the tendency to form mud balls.

Operators of filtration plants should strive to keep the volume of mud balls in the top 6 in. of the beds to less than 0.1 per cent. of the volume of the filtering material.

Jet action at the sand-gravel junction causes ridging of the gravel and may displace the gravel to the extent that sand works its way down through the gravel. A certain gradual transition of size at the sand-gravel junction is recommended.

Various methods of removing the mud from filters are discussed. Restoring a clogged filter to good condition at occasional intervals is not a satisfactory solution of filter bed troubles.

Washing the filters at a very high rate keeps them in better condition than washing at a low rate, but does not keep them in perfect condition. It is difficult to prevent loss of sand when the beds are expanded more than 30 to 35 per cent.

The use of jets of water from a piping grid located above the sand and known as the surface washing system offers the only known practical means of keeping the sand beds as clean as they should be kept. This is used in addition to back washing and at the same time.

The amount of water to be used through the surface washing system varies from about 2 to 8 g.p.m. per square foot, depending on the tendency of the filter to form mud balls or clogged areas. Not many filters will

require a rate of more than 3 to 4 g.p.m. when the pressure head is between 20 and 50 feet at the jets. One-quarter inch holes should be used for pressure heads less than 50 ft., and lesser size holes for higher pressures.

Brass is better than iron for the part of the surface piping system where the holes are located. Holes through iron pipe become larger, owing mainly to corrosion of the fresh iron surface within the hole.

Maintaining filters in excellent condition by use of the surface washing system is not costly.

Tests showing the effectiveness of the surface wash in keeping filter beds clean are given. Other methods of washing which were tried did not keep the beds in satisfactory condition.

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OPERATING EXPERIENCE WITH ANTHRACITE FILTERS.

BY H. S. R. MCCURDY.*

[*Read September 24, 1936.*]

The Philadelphia Suburban Water Company supplies water to forty-nine townships and boroughs located in Delaware, Montgomery and Chester Counties, Pennsylvania. The territory served embraces an area of 300 square miles lying west of the city of Philadelphia. The population by the 1930 census was 316 000 and the number of customer accounts is around 75 000.

There are four sources of supply, all streams sufficiently distant from thickly settled communities to be free from major pollution. The water is coagulated, filtered and sterilized. Prior to coagulation, sulphate of ammonia, activated carbon, alum and chlorine are applied to the water on its way from the reservoir intake to the coagulating basin. On occasions each filter is dosed with three pounds of activated carbon after each washing. Subsequent to filtration, chlorine and lime are added, the latter for the purpose of raising the pH value to 7.2, in order to lessen corrosion in the pipes.

The filters are 1-m.g.d. units of conventional design, excepting that in place of the usual distributing manifold and laterals at the bottom there are bronze nozzles with umbrella caps, embedded in the concrete floor on 12 in. centers. The gravel is 14 in. thick, graded in layers, the sizes ranging from 2 down to 1/10 in. The depth of the sand is 30 in. The lip of the wash-water troughs is 24 in. above the top of the sand.

In order to investigate the merits of anthracite coal as compared with sand as a filter medium, commercial Anthrafilt has been substituted for the sand in certain of the filter units at each of the four plants in the district. At each station the filters containing the Anthrafilt have been operated under exactly the same conditions as a designated sand unit, taken as typical of all the sand filters, in order to obtain a true comparison.

In any discussion of the behavior of anthracite as a filter medium in the plants of the Philadelphia Suburban Water Company it should be borne in mind that it is the policy of this company to use every care in conditioning the water before filtration. This precaution, coupled with the fact that the raw water is of excellent quality, reduces the load upon the filters to a minimum. Furthermore, during the time that comparative observations have been made on the sand and the anthracite filters they were operated only at rates varying from 50 to 70 per cent. of their nominal capacity. It is apparent, therefore, that the filters have not been subjected, as yet, to a severe test.

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For the purpose of this discussion the results at the Crum Creek and the Pickering Creek stations only will be considered, as the information from these plants is the most complete due to the longer time element.

The turbidity of the water applied to the filters during this period was uniformly 2 p.p.m. at each of the stations. At the Crum Creek station the color of the applied water averaged 4 p.p.m. and at Pickering Creek station 7 p.p.m. There was no preference between the two materials in their effectiveness in turbidity or color removal.

It is the practice to carry sufficient chlorine in the applied water to cause a slight residual through the filters. The residual through the coal is consistently somewhat less than that through the sand, due to longer filter runs.

Crum Creek Plant. The filter sand at the Crum Creek station has an effective size of 0.4 m.m. and a uniformity coefficient of 1.47. As compared with this, the Anthrafilt has an effective size of 0.60 m.m. in one filter and 0.70 m.m. in the other, with a uniformity coefficient of 1.60, or less. Both the sand and the Anthrafilt beds are 30 in. deep.

Observations of the two types of filtering material at this station have now been in progress for eight months, covering the period from January to August, 1936. Comparisons were made of the turbidity, color and bacterial count of the effluent. Rates of wash, amount of wash water and duration of wash were studied. The loss of grains was determined and the general condition of the filters examined from time to time.

The results for both materials have been excellent, and there is little to choose between the two as regards filtering efficiency. The effluent from the coal filters has shown slightly higher bacterial counts, but for both kinds of filtering material these counts have been so low as to be insignificant.

TABLE 1.— BACTERIOLOGICAL RESULTS, CRUM CREEK STATION.

Material	Number of Samples.	24 Hr., 37°C. Count per c.c.				48 Hr., 37°C. Count per c.c.				48 Hour Gas Formers.				Coli Aerogenes.
		Zero.		Max.	Avg.	Zero.		Max.	Avg.	+		−		
		No.	%			No.	%			No.	%	No.	%	
Coal...	220	170	77	10	1.0	109	50	180*	7.8	141	13	929	87	0
Sand...	140	123	88	9	0.2	89	64	10	1.8	56	8	639	92	0

* High counts were of rare occurrence.

Table 1 shows comparative results for the Crum Creek station. The difference in number of samples is explained by the fact that for the latter part of the period two coal filters were in service.

It is in the amount of wash water that the greatest difference between the two types of filters is manifested. Here the coal filter shows a distinct

advantage. For the eight months of observation at this station, the average runs for the coal filters were 78 hours and for the sand filter used for comparison, 56 hours. During this period, the percentage of wash water averaged 0.96 for the coal and 1.32 for the sand. Therefore, the coal filters are effecting a saving of 27 per cent. in wash water at this plant. As a matter of precaution the coal filters at the Crum Creek station are washed at 6- or 7-ft. loss of head as against 8 ft. for the sand, but the lengths of runs for the coal filters are limited more by the behavior of the filter than by the loss of head. It was found that with runs exceeding around 95 hours there was a tendency for the effluent to show the presence of gas formers in 48 hours in one or two out of five tubes.

Both types of filter material are washed for 3½ minutes, the sand at a rate of 17 g.p.m. and the coal at 15 g.p.m. per square foot. In the beginning, a small amount of the finer coal was lost, but since the filters have become stabilized there is little, if any, further loss.

Pickering Creek Plant. At the Pickering Creek plant, the coal filter has been in operation for the past five months. The Anthrafilt grains in this filter have an effective size of 0.70 m.m. and a uniformity coefficient of not over 1.60, as against an effective size of 0.38 m.m. and a uniformity coefficient of 1.20 for the sand unit used for comparison.

The behavior of the coal filter at this station was very similar to that at the Crum Creek station, and here again there is little to choose between the filtering efficiency of the coal and the sand.

TABLE 2.— BACTERIOLOGICAL RESULTS, PICKERING CREEK STATION.

Material.	Number of Samples.	24 Hr., 37°C. Count per c.c.				48 Hr., 37°C. Count per c.c.				48 Hour Gas Formers.				Coli Aërogenes.
		Zero.				Zero.				+		−		
		No.	%	Max.	Avg.	No.	%	Max.	Avg.	No.	%	No.	%	
Coal....	88	57	65	35	2.2	37	42	180*	15	44	10	396	90	0
Sand....	88	69	78	12	0.4	55	62	26	3.8	18	4	422	96	0

* High counts were of rare occurrence.

There is, however, a more marked difference in the amounts of wash water than at Crum Creek, possibly due to the greater difference between the sizes of the sand and the coal and also to the fact that at Pickering Creek the filters are run at a somewhat higher rate. The coal filter at the Pickering Creek plant has had an average run of 87 hours as compared with 44 hours for the sand filter operated for comparison. The wash water required for the coal filter has averaged 0.67 per cent. as against 1.16 per cent. for the sand filter. A saving of wash water at this station, therefore, of 42 per cent. has been effected by the use of the coal. The sand filters

were washed at 8-ft. loss of head and the coal filter generally at 6-ft. loss of head, but here, as at Crum Creek, the length of time has influenced the filter run.

Both the sand and the coal filters at the Pickering Creek station are washed at a rate of 14 g.p.m. per square foot. The coal filter is washed for a somewhat longer time than the sand because of the greater thickness of the mat resulting from the longer runs.

Summary. Sand and anthracite filters, identical in construction and operated under exactly the same conditions, have been under observation for eight months at the Crum Creek plant and for five months at the Pickering Creek plant. The results are shown in Table 3.

TABLE 3.— COMPARATIVE RUNS AND WASH-WATER USE IN SAND AND ANTHRACITE FILTERS.

Material.	Effective Size. m.m.	Uniformity Coefficient.	Average Length of Runs. Hours.	Per Cent Wash Water.
Crum Creek Plant.				
Coal	0.60–0.70	1.60	78	0.96
Sand	0.40	1.47	56	1.32
Pickering Creek Plant.				
Coal	0.70	1.60	87	0.67
Sand	0.38	1.20	44	1.16

Daily color and turbidity readings of the effluent show no significant difference between the sand and the coal filters. The chlorine residual carried through the sand filters is greater than that through the coal. Bacteriological results have been uniformly excellent, with the sand filters slightly more efficient.

The observations are still in progress. As time goes on, a greater range of operating conditions is naturally to be expected and will serve to make the comparison more complete. To date the filters have not been operated to their nominal capacity nor have they been subjected to any severe operating conditions.

WATER CHLORINATION EXPERIENCE.

BY FREDERICK O. A. ALMQUIST.*

[*Read February 18, 1937.*]

The importance of chlorination in the disinfection of public water supplies and the safeguarding of public health has been demonstrated and taken for granted for a long time. Despite this, chlorination sometimes does not receive the measure of study that is often afforded to other parts of a water system by the superintendent.

It is the purpose of this paper to discuss chlorination in the light of experiences gained in the disinfection of Connecticut public water supplies, particularly on water supplies where there are not the decided advantages of a chemist and laboratory, in the hope that increased interest will result. Chlorination is not a mysterious thing in actual operation, and a man need not be a chemist or have a college degree to chlorinate a water supply successfully although he does need faithfulness, common sense and in some cases a little ingenuity.

Before launching into the mechanics of chlorination, it seems desirable to discuss plans for installing chlorine equipment and this paper will be separated into two parts, the first part discussing the housing, selection of equipment, location, etc., and the second part, the operation of the plant.

Plant Installation.

Recognizing the importance of proper equipment, location and facilities, the Connecticut State Department of Health asks for a plan and specifications before approval is granted for the construction of a chlorine treatment plant and the use of the equipment. Very little has been published with regard to the preliminary planning for chlorination, yet this is one of the most important features and may easily determine the success or failure of a plant to perform properly the functions for which it was constructed. For example, manual control equipment might be installed where proportional feed equipment should have been used. Equipment manufacturers naturally furnish a great deal of assistance but are not always in a position to know all of the conditions. A recent installation has been held up for several weeks because it was not realized that a drain for the chlorinator building would be necessary; later a right-of-way had to be secured for it. The points to consider are listed in the following paragraphs with brief comments on each subject. In the case of difficult installations, the advice of consulting engineers of experience with chlorination problems may need to be sought as well as the advice of equipment manufacturers.

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Water Consumption. Before any intelligent planning can be done, the amount and variations of the water consumption should be known. A pitot survey or a metered survey should be made to cover a sufficiently long period. This survey should show the maximum and minimum flows during a 24-hour period, effects of industrial consumption, and perhaps Sunday and Monday variations. If possible, seasonal variations should also be known as well as the possibilities of any abnormal peak flows. Fire demands may be very important both with regard to chlorine consumption and any restrictions placed in the supply lines by orifices, motors, etc., that may be installed to proportion the chlorine dosage.

Chlorine Demand. Some knowledge should be obtained as to the approximate chlorine demand that might be expected although this may vary considerably depending on conditions, as discussed later. The chlorine demand at any particular time may be obtained by making up a solution of known strength, adding it in various amounts to samples of water, plotting the amount of chlorine added against the accompanying orthotolidin tests on the chlorinated water and noting the point of sharp increase in the line. This point gives the approximate chlorine demand.

Location of Installation. The location of the installation frequently has some bearing on the type of equipment. Where filter plants are installed or where pumping stations are located at the source of supply, the chlorinator installation is usually a part of the filter installation or is placed at the pumping station. When a chlorine installation is placed in a filter plant or pumping station, safety precautions mentioned later as well as precautions against corrosion of station equipment from occasional escape of chlorine should be observed. Separate rooms are advisable. The majority of our Connecticut supplies are gravity supplies, most of which as yet are unfiltered so that locations of chlorinating equipment are important considerations.

Regardless of the type of equipment, the point of chlorination should preferably be above the first service. Unfortunately, it is sometimes difficult to chlorinate above the first service on existing gravity supply lines and to meet the necessary hydraulic conditions for the installation. This means either that a new supply line must be taken off below the point of chlorination and laid back to the consumers, where economically feasible, or else consumers must be notified that the water supplied to them is not chlorinated and that they should boil their drinking water as a precaution. The first service should be far enough away to assure sufficient contact period between the chlorine and the water to assure as adequate disinfection as possible. Where filter plants are installed, the clear water basin usually provides adequate reaction time. An adequate contact period is essential to obtain the desired bacterial kill. The disinfection may be practically completed in a fairly short period of time particularly if the water is not heavily polluted. A large number of samples have been collected for bacterial analysis from various types of supplies. To many of

these, one or two crystals of thiosulphate were added after the usual 10-minute contact period to neutralize the chlorine and stop the disinfection at this point. The examination of these samples showed the absence of organisms of the coli-aërogenes group. There were undoubtedly a small number of organisms that slipped past the disinfection from time to time and were not caught in the test. It is unlikely that 100 per cent. bacterial kill is obtained in 10 minutes unless the raw water is exceptionally free from pollution or chlorine residuals are maintained that are too high to preclude the possibility of chlorinous tastes and odors. If we take the coli-aërogenes group as an index, it would seem as though it would be fairly safe to recommend a 10-minute contact period with the usual chlorine residual before the water is consumed. An increased contact time, 30 minutes, is recommended when ammonia is employed in conjunction with chlorination because of the slowness or lag in disinfection. This lag has been pointed out by: H. H. Gerstein, Baker and Schmelkes, and others.

Selection of Equipment. Chlorine may be purchased in liquid form under pressure, in solution or in crystal or powdered form from which a solution is usually made. If purchased as a liquid, it may be applied as a gas or as a solution. The liquid chlorine is usually much less expensive than the other forms. When purchasing the chlorine machine, this should be taken into consideration, especially where a large amount of disinfectant is to be used. In this connection, the initial cost of the chlorinators should be weighed with operating expenses. The writer knows of one installation that was displaced by another type of hypochlorite machine to eliminate the cost of operation of an electric motor which ran 24 hours a day, the cost of the machine being saved in less than two years.

It is important to know the pressure in the main. Where appreciable pressures exist, injectors are necessary with most types of machines. Injectors usually need a 3 to 1 operating ratio. For example, if the pressure in the main is 25 lb. per sq. in., the pressure supply to the injector should be about 75 lb. per sq. in. Where the supply is pumped, water from the discharge side of the pump may be used to make up a solution of chlorine in a solution-feed chlorinator. On a gravity line, a reservoir at a higher elevation and not too far away may furnish water under pressure. In most cases, however, a booster pump is necessary. Hydraulically operated pumps in duplicate are preferred in Connecticut to electrically driven motors even though there is quite a little waste in water from the use of these pumps. Interruptions of electric power are an important consideration. Sometimes where waste of water is to be avoided, duplicate sources of power may be provided with electric power normally used and automatic cut-in of hydraulic pumps in case of power failure.

Duplicate chlorinators are generally desirable. In any case duplicate parts in sufficient quantity to assure a minimum in interruption of chlorination should be provided. A relief operator should also be employed who understands the installation thoroughly.

A paper by Charles R. Cox in the Journal of the American Water Works Association, November, 1934, lists the various manufacturers of chlorination equipment and the type of equipment. This list appears to be quite complete.

Housing of Equipment. A number of items of importance may be discussed under the general heading of housing of equipment.

The building should be large enough to house easily all the equipment and should be constructed of good material. A brick house lined with hollow tile, a concrete structure lined with pressed board allowing an air space in back of the board, or a wooden frame structure with a lining of insulating material has been found satisfactory. A fire-proof type building is desirable. In side hills, a dugout type house has been used in several instances, and in some of these cases a cork board insulation has been used. When liquid chlorine is used, the equipment should be above ground, and ventilators in the walls near the floor are desirable. Cross ventilation between the door and a window or between two windows is also desirable. The use of liquid chlorine in a pit or basement without forced ventilation is hazardous. The reason for installing forced ventilation under these conditions is that chlorine is about two and one half times as heavy as air and therefore seeks the low spots.

The size of the building depends somewhat on the type of equipment. A building 8 by 8 ft. in plan with adequate head room is large enough for most hypochlorite feeder installations. With a larger machine operated in conjunction with hydraulic pumps, a neat arrangement results in a building of perhaps three separate compartments: one to house the heater, flow recording device, etc., the second to house the pumps and the third to house the chlorinator. Each compartment would probably be 6 or 8 ft. wide and 12 to 15 ft. deep. If the chlorinator house is in a somewhat inaccessible location, it might be well to allow sufficient storage for chlorine cylinders to carry over the winter months. This also may apply to fuel storage. Space should also be sufficient so that equipment is not so crowded as to make repairs inconvenient.

If solution-feed equipment with hydraulic pumps is used, a gutter or tray on the floor around the equipment is highly desirable, the gutter to discharge to a drain. Splash plates on the wall back of hydraulic pumps are helpful. A good drain at least 6 in. in diameter should be provided, tile being satisfactory. Where hydraulic pumps are used, discharges considerably in excess of 10,000 g.p.d. are frequently encountered, and allowances should be made for this water to be carried away without nuisance or complaint.

If the main is at some distance from the chlorinator, it is a good plan to place the piping or tubing in a tile conduit. This eliminates the necessity for digging a trench to replace the piping when replacement becomes necessary.

Platform scales are a necessary adjunct in the operation of chlorinators using liquid chlorine. In constructing the floor of the building, an inset should be made into which the platform scales will fit so that the platform will be level with the floor. This eliminates lifting the cylinders on to the scales. If much chlorine is used, labor is saved in loading and unloading

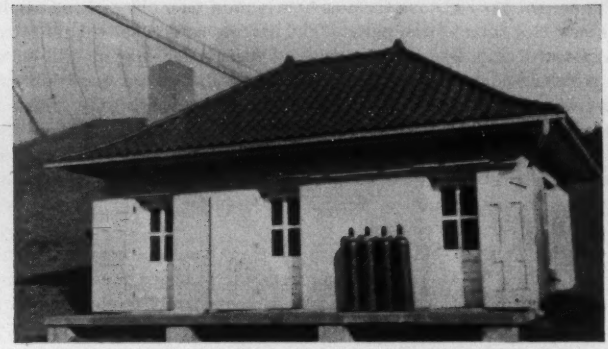

FIG. 1. — CHLORINATOR HOUSE, BRIDGEPORT HYDRAULIC COMPANY.

FIG. 2 — BUILDING FOR HYPOCHLORITE INSTALLATION, SOUTH GLASTONBURY WATER COMPANY.

from a truck by keeping the floor 3 or 4 ft. above the ground level. Figure 1 shows one of three similar chlorinator houses of the Bridgeport Hydraulic Company. Figure 2 shows a building for a hypochlorite installation.

Provision should be made for heating the chlorinator building. For liquid chlorine installations, an even heat of from 50 to 55° F. is desirable

in cold weather where dry-feed equipment is used and from 70 to 80° F. where solution feed equipment is employed. Less heat appears to be necessary for hypochlorite installations, although some heat is required to prevent freezing and to keep the building dry. Chlorine cylinders should not be placed near a heater or in front of a sunny window where the chlorine can be warmed to a temperature above that of the chlorinating equipment. Chlorine hydrate will then form or liquefaction take place in the machine and may clog some of the ports. The heating equipment should provide heat for at least a 24-hr. period without fuel replenishment. Oil burners are popular and satisfactory. For larger installations, a small hot-water boiler with radiators makes a very nice heating arrangement. Some hot water is also available from this type of heater when necessary.

Electric power is very helpful, supplying light for night repairs and when a daylight bulb is used, an operator may make night tests for residual chlorine. In some instances, electricity is used for heating. This has the advantage of excellent control.

Testing Tap. No chlorine treatment plant would be complete without proper facilities for making chlorine tests. It has been found that, under practically all conditions in Connecticut, a good mix is obtained within 200 ft. of the point of chlorine application. With very large pipes, good mixing may not be completed in 200 ft. without special arrangements such as a multipoint application in the main through a special header manifold. At Los Angeles, Cal., this arrangement has nine silver injection tubes located in a 72 in. line. If there is poor mixing, single tests may give unreliable information for setting rates of chlorine dosage. Recommendations are made, under usual conditions, that a testing tap be provided at a distance of 200 ft. from the point of chlorine application with the added suggestion that a line be carried back from the tap to a sink in the building. This is a considerable convenience to the operator and results in more frequent and more faithful testing especially at times of inclement weather. If feasible, a raw-water or untreated-water outlet in the sink is advantageous for raw-water testing or raw-water sampling. An acid resistant sink is preferable to an iron or enamel sink, especially from the standpoint of appearance after having been used a short time.

Gas Masks. Every chlorinator installation should be equipped with a gas mask located outside the area likely to be affected in case of accident and readily accessible. Several types of masks approved by the U. S. Bureau of Mines are available. Instructions accompanying the masks should be obeyed, and all safety precautions should be observed. Operators should be familiar with their use, and the effectiveness of the masks should be checked periodically as recommended by the manufacturers. In using the mask, if fogging of the glasses occurs, a thin coating of glycerine on the inside will be found helpful. Marking the date of receipt of the canister, the date it was first opened and the time of use appears to make a worthwhile record. Within the past year one of our filter-plant superintendents

was hospitalized for practically two weeks because he did not use a gas mask in making repairs in a pit.

It would be well for all chlorinator operators and all water superintendents to read the report of the American Water Works Association Committee on Chemical Hazards in Water Works Plants pertaining to chlorine hazards which appeared in the JOURNAL of September, 1935.

Ton Containers. Only in very large installations, using perhaps 200 lb. per day, is it advantageous to use ton chlorine containers. Recent literature* contains several articles on the use of ton containers and the necessary requirements, so no discussion will be made at this time on that subject.

PLANT OPERATION.

The first water supply to receive chlorine treatment in Connecticut was that of the Stamford Water Company in 1913. This was one of the first in the country. Since that time, chlorination has made rapid strides, and we now have 94 chlorinator installations serving 103 communities, with a total population of 1,139,000, or about 79 per cent. of the population of the state served by public or major semi-public water supplies. Of this population, 91 per cent. depend, so far as treatment is concerned, on chlorine alone for bacterial purification. The importance of chlorination is readily seen. A few supplies are filtered without chlorination.

Before chlorination could be installed in many instances, a natural objection to the addition of chemicals to a water supply had to be conquered and care had to be exercised in order that tastes and odors of a chlorinous nature would not occur to antagonize the consumers. The author is reminded of one water company director who knowing that the water was to be chlorinated, complained that he could not drink the water over the week-end because of the chlorine, only to find later that the inauguration of chlorination was delayed and no chlorine had been applied to the water. A sufficient quantity of chlorine must ultimately be applied to disinfect the supply adequately, and this should be possible without objection. One of the things we have found is that each supply is an entirely separate problem. No two supplies are alike. They are dissimilar in type of watershed, watershed run-off, amount of storage, type of reservoir shoreline, and many other features that affect the chlorination of a supply. There are, however, certain common characteristics or fundamentals in chlorination that hold for each supply.

Chlorine Demand. Each water supply has a chlorine demand which must be satisfied and slightly exceeded before proper chlorination or adequate disinfection can be obtained. This demand varies considerably and sometimes sharply but is closely allied to the amount of organic matter present. This has been evident from graphs showing the color and

* Among some of the recent articles are (1) a description of Chicago's Modern Chlorinating Plant, by A. E. Gorman and H. H. Gerstein, Water Works and Sewerage, December, 1936, and (2) Handling Chlorine to Avoid Trouble by L. L. Hedgepeth, Journal of the American Water Works Association, November, 1934.

the chlorine dosages necessary to maintain a required chlorine residual. The increase in chlorine dosage corresponds closely to an increase in color. Of course, other constituents, such as turbidity and algal growths, also have a bearing on the chlorine demand.

When small reservoir storage exists, an increase in demand usually occurs following an appreciable run-off, and frequent tests should be made so that increased chlorine dosages can be made to offset the increased demand.

It should be pointed out that chlorine continues to be dissipated in the pipe line and as it penetrates the distribution system comes into contact with organic material on the inside of the pipes. On several occasions, the author has tested for chlorine residual at intervals along a pipe line, and in each case the chlorine has gradually decreased until entirely dissipated from one mile to two miles below the point of chlorine application. A disagreeable taste and odor of a chlorinous nature may result from a combination of chlorine and organic matter. In several instances, these disagreeable tastes and odors have been noticeable in distribution systems for a period of time following the inauguration of chlorination until the reaction in the piping system has been completed. This has been avoided in recent installations by carrying a low chlorine residual for a week or two and then gradually increasing the rate of dosage in small increments over a period of four or five weeks to the desired residual.

Chlorine-Residual Test. The chlorine-residual test has been widely discussed in current literature. A chlorinator installation cannot be properly operated without this test. Based on a series of bacterial tests as well as a knowledge of the supply, a certain chlorine residual after a 10-minute contact period is recommended in Connecticut. For surface water supplies, this residual is usually 0.20 p.p.m. Such a residual appears to provide a good margin of safety. In some cases, such as with a large reservoir storage, or where 0.20 p.p.m. residual causes tastes and odors of a chlorinous nature as in a ground water or water of low organic content, a slightly lower residual is allowed. Sometimes as a temporary measure only, such as might occur with algal growths resulting in aggravated tastes and odors, a lower residual has been employed temporarily. Under no condition should it go below 0.10 p.p.m., and in the case of polluted waters, it may be necessary to forget all taste and odor considerations and apply a large excess of chlorine as a safety precaution.

Frequent tests are invaluable. Some time ago, an inspection of a solution feed chlorinator, which was arranged to discharge to waste or to the suction of a pump depending on whether or not the pump was running, indicated that the chlorinator was apparently operating satisfactorily. The gages were normal, and a proper drop in weight of chlorine on the platform scales over a period of time was obtained. However, a negative chlorine-residual test prompted an investigation which disclosed a plugged discharge tube to the pump suction. As the untreated water was fairly good bacterio-

logically, unless a chlorine residual test had been made, the danger might not have been found for a number of days, following the collection of a poor sample. Tests should be made at least daily, and during and after rains and thaws. The results should be recorded. Los Angeles has found the daily variations in chlorine demand of sufficient magnitude to install a residual control machine which makes and records a test every 3 minutes and adjusts the chlorine dosage automatically. These machines make use of photo-electric cells and may prove increasingly popular in the future even though they are somewhat expensive. Favorable records of chlorine residuals may be of much benefit to a water works management in case suspicion is cast on the supply in the event of a disease outbreak in the community served. Of course, honest records are the only ones that are of value. Inaccurate records usually defeat their own purpose in case of trouble.

Considerable research has been done to obtain a reagent that will provide a quick and accurate test for chlorine. Orthotolidin is the reagent generally used and appears to be the best so far discovered, although it has several disadvantages. The main disadvantage is that it is not specific for chlorine. A quantitative, neutral starch-iodide test is described in the 1936 revision of "Standard Methods of Water Analysis"* to be used when the nitrite content of a water exceeds 0.30 p.p.m. or as an alternate to the modification of the orthotolidin test, also described in "Standard Methods," when manganese and iron are present. However, this test involves the use of some laboratory equipment as well as some experience in chemistry and is not easily performed in the field except in some cases. A qualitative starch-iodide test can be made quite easily, although not too accurately. On the whole, with a few simple precautions, the orthotolidin test appears to be the most feasible and accurate test.

The Orthotolidin Test. It is hoped that a brief discussion of the orthotolidin test will not frighten some operators into thinking that the test is too complicated for routine use. The test depends on the oxidation of orthotolidin in an acid solution. To obtain the desired color, the pH of the sample must be below 4.5. Where waters of high pH or high alkalinities are found, more orthotolidin may be necessary than the customary 1 cc. to 100 cc. of water. As long as the pH is low enough, no trouble should be encountered. The author has added 1, 5 and 10 cc. to 100-cc. samples of water from various Connecticut supplies and found no difference in the color of the test. If not enough reagent is used to bring the pH down below 4.5, weird tests or colors sometimes result. The operator of a supply of high alkalinity in the western part of the state was mystified at obtaining a deep brown color on the first rinse after a test. The same color was obtained on the water sample when only a drop or two of orthotolidin was used. A bluish-green color was obtained recently in a swimming pool water. This was avoided when a little more of the acid orthotolidin solution was added. The colors were obtained undoubtedly because of improper pH.

* Published by the American Public Health Association.

Errors in the use of the orthotolidin test may result from exposure of the reagent to strong light, from turbidity and color of water to be tested, from temperature of the water and the presence of nitrite, or from iron, manganese or algal growths in the water. Lignocellulose has been mentioned as producing color with orthotolidin, and there is a possibility that other substances may affect the test.

An unusual interference with the orthotolidin test occurred in a rather new supply a few years ago. Orthotolidin added to the untreated water produced an apparent residual of 0.30 p.p.m. The interfering substance could not be filtered out through filter paper but could be removed by use of a Berkefeld filter. One would naturally suppose iron or manganese in a collodial state might cause the interference, but an analysis for iron and manganese could not account for the entire quantity present. It is not uncommon to obtain tests as high as 0.15 p.p.m. on untreated water in the state.

In most chlorinated waters the presence of nitrite is not a serious problem. The amount is usually quite low and may be oxidized to nitrates by the chlorine. The nitrate content does not affect the test. The oxidation of nitrite to nitrate may increase the chlorine demand and may be the reason for an unexpectedly high chlorine demand on filtered water. Nitrites may be present in filter plant effluents, where ammonia is used, and in swimming pools. A hydrogen peroxide modification has been suggested to oxidize nitrites present, but the method is of doubtful value according to some authorities. If concentrations of nitrite in excess of 0.30 p.p.m. are present, use of the neutral starch-iodide method is recommended, providing laboratory equipment can easily be used.

Iron is not ordinarily a factor in producing errors in the orthotolidin test on Connecticut water supplies. Concentrations in excess of 1.0 p.p.m. are said to cause errors. The 1936 edition of "Standard Methods" outlines a procedure to remedy this, but the procedure is not feasible as a field test.

Manganese is perhaps the cause of most of the interference with the orthotolidin test in Connecticut. It is found in surface water supplies particularly at times of reservoir turnover and is present because of decomposition of organic matter resulting in humic and soil acids in contact with manganous soils. Stagnation of reservoir bottoms favors production of hydrogen sulphide by bacterial decomposition of sulphates. Decomposition causes depletion of oxygen and increase in carbon dioxide. These conditions cause solution of iron and manganese.

Manganese may exist in the manganous form or the manganic form. Manganous manganese must be oxidized to the manganic form to produce a color with orthotolidin. Some natural oxidation takes place, and much of the remainder, if not all, is oxidized by chlorine. In order to obtain a knowledge of the exact amount of chlorine residual present, the amount of interference must be known so that it may be deducted from the final residual test which would include both the chlorine and the interference.

Although all of the interference is not obtained by making an orthotolidin test on the raw water, this test is recommended to the chlorinator operator merely to obtain some indication as to whether interference is present.

Several methods of overcoming manganese interference may be used. The method suggested in the 1936 edition of "Standard Methods" is not easily used in the field as it involves precipitating iron and manganese and centrifuging, although this method could be used at some chlorinator installations. A method which also appears to be more applicable to a laboratory is one suggested by L. Forman of the New Jersey State Health Department. The procedure is to oxidize all manganese in the raw water by first making it strongly alkaline with caustic soda and then bubbling air or oxygen through the solution. The oxidized sample is then neutralized and an orthotolidin test made on it. This result is then deducted from the apparent chlorine residual in the chlorinated water.

Another method, which has much advantage in its simplicity and which is understood to have been recommended by the New York State Department of Health on occasion, is one which involves the collection of duplicate chlorinated samples, one of which is immediately tested with orthotolidin, the other being allowed to stand exposed to the air for 24 hours before being tested. Assuming that the oxidation of manganese and iron is completed at the end of 10 minutes and that the chlorine has been dissipated at the end of 24 hours, if the test obtained at the end of the 24 hour period is deducted from the 10 minute test, the actual chlorine residual should be obtained. One of the main disadvantages is the necessity of waiting 24 hours before obtaining the result and, if necessary, changing the chlorine dosage. Another disadvantage is that it cannot be used when ammonia is employed. This test has been tried a number of times in Connecticut, and some of the high results obtained after 24 hours have convinced the author that care should be exercised in using the test. The vessel holding the 24-hour sample should be unstoppered and should not contain such high chlorine concentrations that undissipated chlorine will remain. It is also quite likely that natural ammonia in the water may interfere, and it is the author's personal opinion that at times of algal growths free chlorine may be bound up in such a way that a test for free chlorine may be obtained on the day after treatment.

The test recommended by the Connecticut State Health Department is that suggested by L. H. Enslow. This test is not entirely accurate but appears to be quite satisfactory. It is easily performed by a chlorinator operator. Two samples of chlorinated water are collected and the first tested with orthotolidin as usual. The second sample is boiled so that about one-fourth of the volume is boiled away to assure that the chlorine is expelled. The sample is then cooled and made up to its original volume with distilled water. This portion is then tested with orthotolidin and the

result deducted from the first test. Many operators make this test using a small alcohol flame to heat the second portion of the sample.

With regard to the orthotolidin reagent, it is felt by the author that its deterioration in light has been somewhat over-emphasized. Two or three water works managements have in the past purchased a gallon of orthotolidin at a time. This solution lasted four or five years, was not kept in the dark all of the time and gave results that appeared to be quire accurate. However, to be on the safe side it is recommended that the solution be kept in the dark and be replaced every six months.

It is suggested that the test be made away from direct sunlight and read preferably in a northern exposure to light. Comparable day and night results would be obtained if an electric daylight bulb were used for all readings. A great many installations, however, do not have electricity.

Testing Outfits and Their Use. A number of testing outfits are on the market. All are, in general, satisfactory. Some employ liquid standards and others colored glass standards. If liquid standards are used, they should be recalibrated at least at the end of two years. From time to time, standards have been found which were not accurate, even glass standards. It is recommended that every testing outfit be calibrated when purchased, if possible, and also from time to time as appears to be necessary.

The outfit must be kept clean, and the test tubes should be washed frequently with warm water and soap and occasionally with alcohol, carbon tetrachloride, acid-dichromate cleaning solution or a cleaning solution of similar nature and then cleaned thoroughly with warm water. Several times, tests have been made before and after cleaning the test tubes with variations in results. It is important that tubes used be matched tubes to avoid interference from a difference in the color of the glass.

Temperature Influence. The temperature of the water has been found to influence the disinfection, the test for chlorine residual and the operation of certain types of chlorinators. Cold water temperatures cause slower reactions, and higher chlorine residuals may be necessary to obtain the desired bacterial kill. On the other hand, during the winter months, the organic content of surface waters is likely to be low, and higher residuals may result in consumer complaints. Close supervision is, therefore, necessary for adequate disinfection without production of tastes and odors.

With regard to the influence of temperature on the orthotolidin test the development of color is slow in cold waters. Water should be warmed to 60 to 70°F. to obtain best results and tests recorded within 10 minutes. If the water is not warmed, a longer time is necessary for the color to develop. It is, however, undesirable to allow more than 20 minutes to elapse, because of the possibility of other complications.

Cold water may affect the operation of chlorinators using liquid chlorine through the formation of chlorine hydrate. Usually, very little heat is required if applied at the proper place. A very slight bleeding of hot water to a tray of a vacuum-type machine will prevent excessive hydrate forma-

tion. A spot electric heater on the incoming water has been used effectively to take off the chill. In two or three instances, a hood over the solution jar heated by electric light bulbs has been used successfully.

Ammoniation. Several water supplies in Connecticut use ammonia in conjunction with chlorination. Ammoniation has a field in the disinfection of water supplies but must be employed with some care. In Connecticut, the installations have usually been made primarily to eliminate tastes and odors of a chlorinous nature and secondarily to obtain persistent chlorination with resulting better disinfection. At no time has the thought of a saving in chlorine been considered of importance.

Chloramines are not so aggressive as chlorine in attacking organic matter and living organisms. Because of this, when ammonia is introduced, with no change in the chlorine dosage, the chlorine residual after 10 minutes usually about doubles. There does not seem to be any increased efficiency from the bactericidal standpoint with the higher residual at this point, so the chlorine residual test recommended is approximately twice that recommended for chlorine alone. The persistence of the chloramine residual into the distribution system may in general be said to have been beneficial in Connecticut in improving not only tastes and odors of a chlorinous nature but also those associated with long pipe lines and dead ends.

Ammonia combines with chlorine to form mono-, di-, or tri-chloramines depending on the pH of the water. Trichloramines are rarely found in waters, however. The literature indicates that both mono- and di-chloramines exist between pH values of 4.5 to 8.4, the ratio of mono-chloramine being greater at pH values approaching 8.5. Disinfection is greatly retarded at higher pH values, and if corrective treatment with lime or soda ash is practiced, this retardation in disinfection should be considered.

The speed of disinfection may be increased by using a higher ratio of chlorine to ammonia but the possibilities of eliminating tastes and odors are decreased. If services are located fairly close to the point of application of chemicals so that contact periods of 30 minutes or more are not available, chlorine may be added before the ammonia, again at the sacrifice of some taste and odor elimination, but retaining the chloramine persistence.

All chlorine tastes and odors are not eliminated when ammonia is used. Experiments must be made on the particular water to be treated and the ratio of ammonia to chlorine determined from these observations. This is not a fixed ratio and will change depending on conditions. When ammonia was first used, the ratio of ammonia to chlorine was generally set at 1 to 2 or 1 to 3, the dosage being that necessary to obtain at least twice the residual obtained with chlorine alone. However, better taste and odor conditions appear to be effected if lower ratios are maintained, perhaps in the vicinity of 1 to 4 or 1 to 6, still retaining the usual chlorine residual. In one case in Connecticut it was necessary to shut off the ammonia entirely for a few days to eliminate objectionable tastes described as of a medicinal nature. The greatest difficulty probably results from the

fact that most of the ammonia installations are manual control machines with proportional-feed chlorinators on gravity supplies with fluctuating flows, causing variations in ratios.

There also appears to be some possibility of the chloramines being broken down in hot-water systems with evolution of free chlorine.

Operation. Complete details of chlorinator operation cannot be given here. However, a few points not yet mentioned seem pertinent. An installation should be visited at least every day to observe the functioning of the chlorinator equipment, to make required tests, to weigh chlorine cylinders and to record operating procedures. In one instance in Connecticut, a chlorinator was rendered inoperative between daily visits of the operator by some person firing a bullet through the window and striking the machine. It is important that platform scales be used to check the operation of the installation and inform the operator when the chlorine cylinders are becoming depleted. Two or more cylinders may be used at once. If two are used and one is less full than the other, nearly the same amount of chlorine will be drawn from each. By this arrangement the chlorine may be drawn out to a minimum and chlorine will not be entirely depleted during the absence of the operator. The operator can also change cylinders without shutting down the machine. In general, about 40 lb. of chlorine per day may be drawn from 100- to 150-lb. cylinders.

If hypochlorite is used, care should be exercised to ascertain that there is a sufficient amount of solution to last until the next visit. In starting a new installation, it is suggested that only about one-half the content of the crock be made up with solution to allow for dilution should the chlorine demand of the water be less than anticipated. A second crock should be on hand so that an entirely new solution can be made up when the supply nears depletion.

Chlorine Complaints. The majority of complaints received in connection with chlorination are those of tastes and odors of a chlorinous nature. These may be caused by the combination of organic matter with chlorine or chloramines when not due to excess chlorine. Normal operation without tastes and odors may quickly be upset by a rather sudden increase in organic matter in a reservoir such as might occur from a quick algal growth, a heavy rain or high winds. Tastes and odors are likely to accompany the spring and fall reservoir overturns, more especially the fall overturn. Periods of spring thaw causing a run-off from melted snow may cause troublesome conditions. Frequently, of course, tastes and odors attributed to chlorine would be present in the absence of chlorination.

Other types of complaint, too, are received because of chlorination. What superintendent has not had a complaint that the chlorine was killing the gold fish? Investigations of a number of complaints have failed to indicate in any case that chlorine was responsible for this. In one case, in a store, the gold fish were killed by a leaking check valve on the car-

bonation machine. The circulating water in the fish pool was carbonated water. It is felt that two causes are frequently responsible for the destruction of gold fish: a quick change in water temperature or over-feeding so as to foul the water. If these are not direct causes of death, in many cases the fish are so weakened that they succumb to natural fish diseases. We have had no complaints that chlorinated water was causing sterility in a person as was mentioned by George C. Bunker in his paper before this ASSOCIATION on South American practice. We did have a recent complaint that the chlorine in the water lowered the butter-fat content in milk.

Miscellaneous Chlorine Uses. Chlorine is used quite frequently in sterilization of new mains in Connecticut. The practice has been to recommend a dosage of at least 3 p.p.m. and allow as long a contact period as feasible, several hours or more being preferable. This may be done by using a chlorine machine and applying chlorine to the water or by adding a small amount of H.T.H., Perchloron or other chlorine compound of high chlorine concentration at intervals when the pipe is laid. One water works management places one-half pound of H.T.H. in the pipe at intervals of 100 ft. as the pipe is laid. This corresponds to 18 p.p.m. of chlorine in a 6-in. pipe and 3 p.p.m. in a 16-in. pipe. It is felt that a standard procedure as to dosage outweighs any saving that might result in a smaller application for the smaller diameter pipe. A chlorine compound should not be placed in the inside of a cement lined pipe as the chlorine will attack it.

The author has used chlorine to disinfect a pressure filter on an occasion when bacterial counts in the filtered water greatly exceeded those of the raw water. Sufficient chlorine was added to water on the top of the filter to obtain a slight residual in the waste water. When using this means, the filter should be flushed and washed thoroughly, as a very disagreeable taste and odor results in the water. A similar method to remedy algal conditions caused clogging of a small slow sand-filter and it had to be thrown out of operation and raked. On a large slow sand-filter, chlorine was used successfully to eliminate algal growths.

A new standpipe was recently disinfected on one of our Connecticut public supplies. It is a covered steel tank 40 ft. high and 30 ft. in diameter, having a capacity of 200,000 gal. It was filled and dosed with 30 lb. of H.T.H., which corresponds to a dosage of 12 p.p.m. The dose was applied by spreading the powder over the surface, although the effect would probably have been quicker had the H.T.H. been made into a solution first. The results of orthotolidin tests were as follows:

2-hr. contact, residual chlorine at top of tank—5.0 p.p.m.
2-hr. contact, residual chlorine at bottom of tank—Trace.
2½-hr. contact, residual chlorine at bottom of tank—0.10 p.p.m.
2¾-hr. contact, residual chlorine at bottom of tank—0.15 p.p.m.
3-hr. contact, residual chlorine at bottom of tank—0.35 p.p.m.
3¼-hr. contact, residual chlorine at bottom of tank—2.0 p.p.m.

The standpipe was then drained and rinsed three times by filling to a depth of a few inches and flushing out. After this no free chlorine was present and the tank was placed in operation.

Prechlorination. Prechlorination has not been practiced except for short periods in one or two instances in the filtration plants of Connecticut. Most of them with small changes can prechlorinate should it seem desirable.

Conclusion.

The chlorination of public water supplies is a very important feature in the safeguarding of the supplies, the importance increasing when chlorination alone is relied upon for bacterial purification. Before making a chlorinator installation, careful consideration should be given to location of the plant, selection of the equipment and construction of the housing. After the installation has been completed and operation begun, precautions should be observed both with regard to the supervision of the mechanics of chlorination and the use of the test for chlorine residual. Periodic bacteriological examinations of the water should be made as a final measure of control.

CHLORINATION OF A CAMBRIDGE MAIN.

BY FRED E. SMITH.*

[*Read February 18, 1937*].

In 1931, as a part of the expansion program of the Cambridge distribution system, a 30-in. cast-iron pipe line was laid on Broadway. The total length of the pipe line from the Common near Harvard Square to Third Street in East Cambridge was approximately 10 900 ft. Gate valves were installed at intervals in the pipe line, dividing it into sections; small valves were in place to release air as sections of the line were filled with water, and some corporation cocks had been made ready for house connections.

During construction, the pipe line had been subjected to pollution hazards. In one instance, a sewer line had been accidentally broken, allowing sewage to enter the pipe trench before the sewer could be repaired. Minor collapses of the trench walls had caused earth and débris to contaminate several lengths of pipe. Before being placed in the trench, lengths of pipe had remained at the street curb until used, and so had been in danger of the chance pollution common to city streets.

It was decided, therefore, that disinfection of the pipe line was required before putting it into service. For this work, a portable chlorinator was lent to the Water Department by the Massachusetts State Department of Health. This apparatus, built for emergency chlorination, had a capacity of 40 lb. of chlorine per 24 hours. The gas could be forced into the water in the pipe line by means of the pressure in the chlorine cylinder, provided that the pressure exerted by the water in the pipe did not exceed 25 lb. per sq. in. Another method of applying chlorine with this apparatus involved the use of a pump and suitable fittings by means of which the chlorine could be added to the water as a solution feed. As water for solution feed was not readily available, and as the work was scheduled to be performed in December with possibilities of freezing temperatures, the method selected was that of feeding the gas directly into the pipe line from the chlorinator. A diffuser was used which could be inserted into the pipe line through a corporation cock.

Before the arrangements for chlorination could be completed, the several sections of the pipe line between gate valves had been filled with water in order to test the pipe for leakage. No services were supplied with water at this time. This condition not only caused considerable loss of time in chlorinating the pipe line, but also modified the planned procedure for doing the work. It called for displacement of the water in the sections.

Using the chlorinator, a cylinder of chlorine, and the services of two men with the supervisor, the pipe line was chlorinated by sections in the

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following manner: After placing the cylinder and chlorinator on the sidewalk beside the trench, the chlorinator with tube and diffuser was connected to the pipe line at a corporation cock. The apparatus was located at one end of a pipe line section which was cut off by gate valves. The small blow-off valve at the other end of the section was then opened. The gate valve at the chlorinator end of the section was next opened slightly to force water through that section.

With only the small blow-off valve available to release water during chlorination, the displacement of water through the pipeline section was very low. Another condition limiting the rate of flow of water was the necessity of keeping within limits the pressure of water in the pipe. If the water pressure exceeded 25 lb. per sq. in., difficulty was encountered in forcing the gas into the water. These factors, together with delays caused by needed adjustments of the chlorinator, prevented in some instances a positive test for residual chlorine being obtained at the blow-off valve during active chlorination. Limited time for certain work periods also affected the collection of samples indicating residual chlorine. Actually, the procedure resulted in heavily over-chlorinating the water in the pipe line section immediately adjacent to the apparatus. As soon as possible, this pipe section was flushed for a sufficient number of hours so that the heavily over-chlorinated water travelled the entire length of the section and accomplished disinfection.

Based on the weight of chlorine used and the volume of water in the pipe-line sections, the dosage of chlorine was 12 p.p.m. During the prolonged flushing operations, residual chlorine tests were made. When the sample had a high turbidity due to dirt, considerable interference with the orthotolidin test resulted. Color in the Nessler tube produced by the combination of indicator and residual chlorine was observed, but estimation of the chlorine value could not be recorded when the sample was compared with standards. After continued flushing for several hours had discharged water having a strong chlorine odor, residual chlorine tests showed the presence of 0.3 p.p.m. Turbid water and substances capable of causing difficulty with the orthotolidin test by this time had been eliminated from the pipe, and the test for residual chlorine could be successfully made.

When flushing of the pipe section had been completed, the efficiency of the chlorination procedure was checked by the examination of samples of water in the laboratory. Bacteriological examinations of the water were made using agar plates incubated for 24 hr. at 37°, and tests for *B.coli* were prepared. The results of the examinations showed 1 or 2 bacteria on agar per cubic centimeter of water, and the tests for *B.coli* were negative. Chemical analyses indicated that the water then had the normal characteristics of Cambridge tap water when examined for color, alkalinity, pH, carbon dioxide, and absence of chlorine odor.

After the results of the laboratory examinations indicated that the water in the pipe line was safe for human consumption, the several sections

of the line were placed in service as required. No complaints of chlorine odor or taste were received, indicating that all heavily chlorinated water had been flushed from the pipe and replaced with water of normal chlorine content.

It is recognized that quicker and perhaps more efficient chlorination could have been accomplished, had the chlorination facilities been available when the sections of pipe line were filled for the first time. Chlorine in more moderate dosage could have been applied as the pipe slowly filled, and when full the treated section could have been allowed to remain undisturbed until disinfection had been completed. After flushing-out the chlorinated water, the line would have been ready for service. The effects of water pressure, which gave considerable trouble during chlorination by the selected method, would have been largely eliminated, and an application of chlorine would have been possible which would have reached all parts of the section at nearly the same time.

During chlorination, it was found that in only one section of the pipe line was the water decidedly dirty, indicating that reasonable care had been used by the contractor during construction. This condition also showed careful inspection work by water department maintenance men during the laying of the pipe.

EXPERIENCES WITH CHLORINATING NEW WATER MAINS.

BY GEORGE O. ADAMS* AND FRANCIS H. KINGSBURY.†

[*Read February 18, 1937.*]

Considerations of public health and cleanliness have caused those interested in safe water supplies to recommend the disinfection of new structures and new water mains before such works are placed in use. Papers, read before this ASSOCIATION have told of experiences in particular instances in which water mains have been disinfected successfully with chlorine.

Difficulties Encountered. During the summer of 1936, the Massachusetts Department of Public Health was called upon to advise certain municipalities on the chlorination of water mains and came upon unusual difficulties in obtaining satisfactory bacterial results after the mains had been chlorinated and thoroughly flushed. In more than one instance repeated chlorination and flushing of the mains was necessary before satisfactory bacterial counts could be observed. Table 1 summarizes experiences in five separate municipalities between June and December, 1936.

In these five municipalities the water was supplied from ground water sources free from bacteria of the coli-aërogenes group. When the difficulties of obtaining satisfactory results were first encountered it was thought that the sampling points were unsuitable. In some cases hydrants had been selected because no taps were available. It has been the general experience during the course of this study that hydrants do not make the best sampling points. In general, available taps or taps installed for the purpose were found to be the most satisfactory means for taking samples. Because of the extended length of time during which positive coli-aërogenes tests were obtained, it was impossible to believe that the effect of any polluted material which might have been in the pipes during their installation could have persisted after the thorough chlorination and flushings.

Suspicion fell upon the only organic substance in the pipe lines, namely the packing used in the joints. Samples of the packing used on certain of the installations were examined for the presence of bacteria of the coli-aërogenes group with some interesting discoveries.

At this point it may be well to state that we are not prepared to say that the results of the findings indicate danger to health in the use of the materials studied. The use of these materials in the form in which they

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are now marketed, however, makes it difficult in certain circumstances to properly interpret the results of bacterial examinations of samples of water collected from new mains.

The description of the studies conducted by the senior author, and the results attained will be presented as prepared by him.

Bacteriological Experiments. As stated, the failure to remove coli-aërogenes organisms from new mains by heavy chlorination led to the search for their origin in some other source than accidental contamination of the pipe during the process of laying. The most likely source seemed to be in the rope used in calking the joints. A preliminary examination of a number of samples of jute rope showed the presence of members of the coli-aërogenes group in numbers ranging from 10 to 1 000 per gram of jute.

The procedure followed in the bacterial examination of jute samples was to place one gram of sample in a bottle containing 100 c.c. of sterile water and shake thoroughly. Bacterial counts were expressed in terms of one milligram of the sample. After portions of the water had been taken for analysis to show the bacterial content of the jute, the bottle containing the jute and the water was allowed to stand at 70°F. This temperature was selected as a convenient one and is about the summer temperature of surface waters in water mains. Daily tests were made, usually for 12 or more days. On standing at 70°F. the numbers of bacteria of all types increased enormously. The numbers of bacteria in 16 samples of jute as received and after standing in water for three days are shown in Tables 2 and 3. Inclusion of the daily results would have made the tables too large. The period of three days was selected, as by this time the numbers had reached approximately their maximum, and later results were somewhat irregular. In Table 4, the daily results are shown for one sample, which is representative of all except tarred samples.

The enormous growths of bacteria in the jute and water mixtures show plainly that the jute contains food material for the bacteria. Ten grams of Jute No. 1 were placed in three liters of distilled water and allowed to stand 24 hours at 70°F. The soluble matter was found to be equal to 2.79 per cent of the jute and contained 1.83 per cent organic nitrogen and no fermentable sugar. In another test, a portion of the jute was placed in distilled water, brought to a boil, and boiled five minutes. After cooling, the water as decanted and replaced with fresh water and boiled again. This was repeated until the jute had been boiled ten times. By this time most of the soluble matter had been removed. Probably small amounts of organic matter would still have dissolved if the boiling had been continued indefinitely. By this treatment 4.46 per cent of the jute was rendered soluble. The organic nitrogen content of the soluble matter was 1.58 per cent. Some of this extract was concentrated to one-fourth of its volume and used instead of peptone and meat extract in making nutrient agar. The counts on plates made with this agar averaged nearly as high as with

TABLE 1.—RECENT EXPERIENCES WITH CHLORINATING WATER MAINS.

Time. (Days).	Operation.	Coli-Aërogenes Positive in
	Municipality "A".	
Start	Mains flushed — Sample taken	0 to 1 c.c.
3	Mains flushed	.....
4	Samples taken	0 to 1 c.c.
7	Mains flushed	.....
8	Samples taken	0 to 1 c.c.
15	Mains chlorinated — 10 p.p.m	.....
17	Samples taken	0 to *4 of 5–10 c.c.
Start	Additional mains chlorinated	.....
2	Samples taken	0 c.c.
Start	Additional mains chlorinated	.....
7	Samples taken	0 to 1 of 5–10 c.c.
Start	Additional mains chlorinated	.....
6	Samples taken	0 to 5 of 5–10 c.c.
14	Chlorinated again	.....
25	Samples after 11 days	0 to 1 of 5–10 c.c.
Total, 158 days		

* No residual chlorine.

	Municipality "B".	
Start	Supply and mains chlorinated	.....
2	Chlorinated water drained off	.....
4	Mains flushed	.....
5	Samples taken	0 to 1 c.c.
Start	Supply chlorinated	.....
1	Mains chlorinated	.....
4	Mains flushed	.....
6	Samples collected	0 to 0.1 c.c.
Start	Mains chlorinated	.....
1	Mains chlorinated	.....
4	Mains flushed	.....
5	Mains flushed	.....
6	Mains flushed — Samples taken from hydrants	0 to 1 c.c.
11	Samples taken from taps	0 to 3 of 5–10 c.c.
Start	Mains chlorinated	.....
1	Mains chlorinated	.....
5	Mains flushed	.....
7	Samples taken from hydrants	0 to 0.1 c.c.
Start	Parts of system chlorinated	.....
5	Samples taken from hydrants	0 to 0.1 c.c.
Start	Parts of system chlorinated	.....
5	Samples taken from hydrants	1 c.c.
11	Mains flushed	.....
12	Samples taken from hydrants	3 of 5–10 c.c.
Total, 75 days		

TABLE 1.— RECENT EXPERIENCES WITH CHLORINATING WATER MAINS — *Continued.*

Time. (Days).	Operation.	Coli-Aërogenes Positive in
	Municipality "C".	
Start	Elevated tank chlorinated	.....
1	Mains filled with chlorinated water	.....
4	Mains flushed	.....
5	Mains flushed	.....
5	Samples taken from hydrants	0 to 0.1 c.c.
Start	System chlorinated by pumping chlorinated water and maintaining 0.2 p.p.m. residual	.....
2	Samples taken of chlorinated water from hydrants	0 to *1 c.c.
8	Stopped chlorinating	.....
9	Pumped raw water	.....
10	Mains flushed	.....
11	Mains flushed	.....
12	Samples taken from hydrants	0 to 0 1 c.c.
Start — 10	Pumped chlorinated water and wasted	.....
11	Stopped chlorinating	.....
12	Samples taken from hydrants	0 to 5 of 5–10 c.c.
Start	Chlorinated part of system not thoroughly flushed	.....
2	Samples taken from hydrants	0 to 5 of 5–10 c.c.
2	Samples taken from taps	0
Total, 46 days		
	Municipality "D".	
Start	Tank chlorinated	.....
1	Mains flushed	.....
1	Tank chlorinated again	.....
3	Mains filled with chlorinated water	.....
10	Mains flushed by pumping	.....
12	Samples taken from hydrants	0 to 2 of 5–10 c.c.
Total, 12 days		
	Municipality "E".	
Start	Standpipe chlorinated	.....
1	Mains filled with chlorinated water	.....
3–7	Standpipe filled with clear water	.....
7	Mains flushed	.....
7	Samples	2 of 5–10 c.c. to 4 of 5–10 c.c.
11	Samples	0
Total, 11 days		

* No residual.

TABLE 2.— BACTERIAL QUALITY OF UNTREATED JUTE AS RECEIVED.
1 Gram of Jute Placed in 100 Cubic Centimeters of Sterile Water.

Jute No.	At Start.				After 3 Days at 70°F.			
	Bacteria per Milligram.			Coli-Aërogenes per Milligram.	Bacteria per Milligram.			Coli-Aërogenes per Milligram.
	4 Days 20°C.	24 Hr. 37° C.			4 Days 20°C.	24 Hr. 37°C.		
		Total.	Red.			Total.	Red.	
1.	..	..	..	0.01	..	..	..	10
2.	..	..	..	0.01	..	..	..	10
2.	110	26	0.5	0.01	180	230	45	10
3.	..	..	..	0.01	..	..	..	1
4.	220	26	1.5	1	1 400	650	230	100
5.	250	57	1	1	1 000	710	45	10
6.	4 600	76	19	1	3 500	18	0.4	0.01
8.	175	17	0.1	0.1	450	80	20	10
10.	210	69	23	1	4 600	560	150	100
13.	760	140	40	0.1	4 800	1 400	250	100
14	2 800	280	20	1	4 300	770	210	100

TABLE 3 — BACTERIAL QUALITY OF TREATED JUTE AS RECEIVED.
1 Gram of Jute Placed in 100 Cubic Centimeters of Sterile Water.

Jute No.	At Start.				After 3 Days at 70°F.			
	Bacteria per Milligram.			Coli-Aërogenes per Milligram.	Bacteria per Milligram.			Coli-Aërogenes per Milligram.
	4 Days 20°C.	24 Hr. 37°C.			4 Days 20°C.	24 Hr. 37°C.		
		Total.	Red.			Total.	Red.	
Tarred: 7	1 800	21	0	0	20 000	120	5	0
9	12	1	0.1	0	1 500	5	0	0
12.	630	0.9	0	0	550	1	0	0
16.	9	5.4	0	0	20 000	3 600	0	0
16.*	..	..	..	..	920 000	650 000	120 000	10 000
Waxed: 11.	5	1.1	0.3	0	3 200	20	13	0
Oiled: 15.	690	200	33	1	4 700 000	1 600 000	450 000	100 000

* After 6 days.

TABLE 4.— INCREASE IN BACTERIA FROM UNTREATED BRAIDED JUTE No. 4.
1 Gram of Jute Placed in 100 Cubic Centimeters of Sterile Water and Kept in Laboratory at 70°F.

Time.	Bacteria per Milligram.			Coli-Aërogenes per Milligram.
	4 Days 20° C.	24 Hr. 37°C.		
		Total.	Red.	
Start	220	26	1.5	1
1 Day	78 000	9 000	2 800	100
2 Days	2 300 000	710 000	340 000	100 000
3 Days	1 400 000	650 000	230 000	100 000
4 Days	3 000 000	1 900 000	200 000	1 000 000
5 Days	11 000 000	1 100 000	150 000	1 000 000
7 Days	4 000 000	3 500 000	550 000	100 000
8 Days	7 000 000	2 100 000	420 000	100 000
9 Days	4 900 000	750 000	120 000	100 000
10 Days	4 600 000	2 000 000	180 000	10 000
12 Days	11 000 000	1 500 000	250 000	10 000
14 Days	6 100 000	610 000	190 000	100 000
15 Days	4 200 000	270 000	90 000	100 000
16 Days	6 600 000	1 200 000	240 000	100 000
17 Days	7 400 000	390 000	140 000	100 000

TABLE 5.— RESULT OF TREATING JUTE No. 2 IN LABORATORY.
1 Gram of Jute Placed in 100 Cubic Centimeters of Water.

Treatment.	Water Used.	At Start.				After 3 Days at 70°F.			
		Bacteria per Milligram.			Coli-Aërogenes per Milligram.	Bacteria per Milligram.			Coli-Aërogenes per Milligram.
		4 Days 20°C.	24 Hr. 37°C.			4 Days 20°C.	24 Hr. 37°C.		
			Total.	Red.			Total.	Red.	
Boiled and Dried.	Lawrence tap and 1% river water.	23	0 3	0	0.01	330 000	12 000	130	10
Boiled and Dried	Andover tap	4.2	0.1	0	0	2 100	1	0	0
Boiled and Dried	Sterile	0.9	0.05	0	0	2 900	60	0	0
Autoclaved	Lawrence tap and 1% river water.	120	1.0	0.3	0.01	2 900 00	83 000	65 000	10 000
Autoclaved	Andover tap.	2.3	2.6	0	0	14 000	340	0	0

TABLE 6 — RESULTS OF CHLORINATING JUTE NO. 4, IN BRAIDED FORM
10 Grams of Jute Placed in a Liter of Solution Containing 10 Parts per Million of Chlorine, Rinsed and Transferred to Sterile Water.

Time of Contact.	At Start.				After 3 Days at 70°F.			
	Bacteria per Milligram.			Coli-Aërogenes per Milligram.	Bacteria per Milligram.			Coli-Aërogenes per Milligram.
	4 Days 20°C.	24 Hr. 37°C.			4 Days 20°C.	24 Hr. 37°C.		
		Total.	Red.			Total.	Red.	
Start	220	26	1.5	1	..	..	..	..
One Day	11	4.9	1.0	1	670 000	51 000	28 000	10 000
Two Days	280	17	1.7	1	370 000	34 000	13 000	10 000
Four Days	610	170	36	10	98 000	19 000	1 500	100
Two Weeks	1 700	260	21	0.1	160 000	2 700	400	10
*One Day Contact	56	5.8	0	0	4 000	23 000	0	0

* Jute No. 4 Unbraided and strands laid open.

TABLE 7.— ARTIFICIAL GROWTH OF TYPHOID BACTERIA.
Jute No. 4, Autoclaved, Placed in Sterile Water and Inoculated with a Pure Culture of *E. Typhosa* and Kept at 70°F.
Samples Plated on Bismuth Sulphite Agar.

Time.	*E. Typhosa* per Milligram of Jute.	Time.	*E. Typhosa* per Milligram of Jute.
Start	12	7 days	13 000
1 day	51	8 days	1 700
2 days	81	9 days	23 000
3 days	190	10 days	17 000
5 days	2 100	12 days	8 000
6 days	9 000	13 days	1 200
		14 days	700

regular agar, proving that organic matter in the jute is suitable for bacterial growth.

In Table 5 some tests are shown with this boiled and dried jute and with jute that had been held in an autoclave for 15 minutes under 15 pounds pressure. Tests showed that this treatment completely sterilized the jute. The removal of most of the soluble matter by boiling reduced the ability of the jute to support a heavy bacterial growth. The sterile jute when brought in contact with polluted water gave a large increase in bacteria on standing. Some of the jute samples were in the form of loosely twisted rope and some in hard braided form.

To show the effect of chlorination in sterilizing jute the following tests were made. Ten-gram pieces of the braided jute were placed in a liter of water containing 10 p.p.m. of chlorine as hypochlorite and allowed to stand at 70°F. Additional chlorine was added from time to time to maintain a concentration of 10 p.p.m. The results in Table 6 show that two weeks' contact was insufficient for sterilization, although the number of coli-aërogenes organisms was reduced. When the chlorine solution was rinsed from the jute and it was placed in sterile water the portions that had been subjected to the longest contact with chlorine gave the lowest number of bacteria in three days. This is probably due to the fact that more of their food supply had leached out into the chlorine solution.

This series illustrates the difficulty in sterilizing any jute in pipe joints that may be in contact with the water in the pipe. The incomplete sterilizing action of the chlorine is undoubtedly due to the inability of the chlorine solution to reach the interior portions of the rope before its strength is exhausted. When the jute is unbraided and the strands are laid open, coli-aërogenes organisms are completely removed in one day's contact.

In another test some sterile autoclaved jute was placed in sterile water and inoculated with a pure culture of *Eberthella typhosa* and kept at 70°F. Counts made on bismuth-sulphite agar showed an increase in numbers, which, while somewhat slower than that with coli-aërogenes organisms, reached a maximum of 23 million per gram of jute. This shows that pathogenic bacteria, such as typhoid organisms, can grow on jute under favorable conditions. (Table 7.)

Besides the 11 samples of untreated jute, shown in Table 2, four samples of tarred jute were examined. Three of these showed no coli-aërogenes organisms even after standing three days in sterile water, and comparatively low numbers of other bacteria. One sample showed no members of the coli-aërogenes group after standing three days but did show a large number after standing six days. A sample of waxed jute showed no coli-aërogenes organisms even after six days. A sample of oiled jute behaved about the same as untreated jute. Thorough tarring of jute seems to handle the coli-aërogenes question but its use would probably be undesirable in chlorinated waters because of the possible production of tastes.

These tests show that jute carries food material for bacteria, and that when any jute in the joints of water pipe is exposed to contact with the water, bacteria increase in number and spread into the water in the main. It is not intended to claim that the growths of bacteria obtained in the laboratory tests duplicate conditions in the mains where an uncertain amount of surface is exposed to the water and the jute is very densely packed. It has been shown that of 11 samples of untreated jute examined, all contained coli-aërogenes organisms, and all gave enormous increases in the number of these bacteria when in contact with water for three days or more. Steam-sterilized jute in contact with water free from coli-aërogenes organisms will develop no growth of these bacteria, but in contact with a polluted water may become infected.

In sterilizing jute by steam, conditions must be such that moist steam penetrates thoroughly into the rope or braids. A thorough boiling of jute should kill all members of the coli-aërogenes group and cut down the food supply for all bacteria.

In all the 11 untreated jutes examined, both *B. coli* and *B. aërogenes* were isolated. No definite statement can be made as to the sanitary significance of coli-aërogenes organisms in jute other than to say that for the present they must be considered on the same basis as members of the coli-aërogenes group from any other source.

Conclusions. Similar experiences were reported by John S. Gettrust in a paper presented before the Ohio Conference on Water Purification in October 1932. In his paper he referred to a publication by Charles H. Spaulding in *Public Health Engineering*, December 1931. In a thesis prepared at the Massachusetts Institute of Technology by Stuart Jackson Hayes in 1918, there are drawn some interesting conclusions with which the authors are not as yet prepared to agree.

As a result of the bacteriological work at the Lawrence Experiment Station it has been demonstrated that the jute supports bacterial life and though sterile when placed in the pipe may be inoculated by the water coming in contact with it. The number of bacteria may increase and be washed off into the water causing high bacterial counts although the water upon entering the pipe may have contained but few bacteria.

There appears to be a tendency to minimize the significance of unsatisfactory bacterial results obtained when certain new mains are tested, but this attitude does not appeal to those responsible for the safety of the system. There is in this subject a direct challenge to manufacturers to develop a product that is mechanically satisfactory and that at the same time will not impart odor or taste to the water or take from the sanitarian the generally accepted yard stick for measuring the degree of cleanliness of water.

PUBLIC HEALTH ASPECTS OF THE FLOOD OF MARCH, 1936 IN NEW YORK STATE.

BY ANSELMO F. DAPPERT.*

[*Read September 23, 1936.*]

What to do in case of emergency is a matter that might be considered with profit by all persons concerned with operating public water supplies or maintaining supervision over their safety. It is a matter that may well be considered with respect to the many catastrophes that may cause disruptions of water service or jeopardize the safety of water furnished to the public. Fires, droughts, floods, sleet storms, hurricanes, tornadoes, earthquakes, and "freeze-ups" are all catastrophies in question. The real worth of a waterworks operator may be more amply demonstrated by the test of an emergency than by the performance of his normal routine duties. In the last analysis, the water works superintendent or operator is the single individual upon whom continuity of service and safety of the supply depend. No public water supply, as a general rule, can be more dependable or safer than the person entrusted with the responsibility for its care and operation. Occupying such an important and responsible position of trust, it behooves the superintendent or operator to look not only after essential routine duties connected with operation, but also to search out those weaknesses in the system, which, particularly in time of disaster or under unusual conditions of any kind, may develop under stress and produce failure or serious contamination of the supply.

Floods are to be considered in this discussion as one type of disaster that may place upon the shoulders of health departments or water works officials a burden greater than they can bear, with consequent breakdown in the ordinary barriers set up against transmission of disease. It should be our purpose to seek out of the experiences of the past and consideration of the future some plan of action which, when pursued in ordinary times, will be adequate to meet the exigencies of an emergency and lessen the burden to such a degree that it can be borne. The recent flood experiences in New York State in July, 1935 and March, 1936, together with the experiences suffered elsewhere throughout the flooded regions of other states, should make it possible to formulate, within broad general limits at least, some definite plan for the guidance of health departments, health officers, and water works and other local officials in times of flood disasters or emergencies.

New York State experiences in the July, 1935 flood, as far as public health aspects are concerned, are recorded fairly completely in a paper presented before this ASSOCIATION in September, 1935. For purposes of

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record, it remains now to bring this general information up to date by giving some account of the experiences suffered during the March, 1936 floods.

In passing, it is well to point out that the causes and effects of the 1936 flood were quite different from those of 1935 and that the procedures and methods followed to meet the emergency problems, therefore, although similar, were modified to fit the different circumstances. This is mentioned to illustrate the fact that it would be difficult to work out a definite and exacting plan in great detail for emergency sanitation work during floods. Certain essential services rendered by Department of Health engineers during the 1935 flood were not supplied during the 1936 flood due to differences in the character of problems arising from the two disasters and the fact that other agencies by reason of their experiences of a few months earlier were well prepared to handle certain phases of the work which in the previous flood had been organized and directed to a considerable extent by Department engineers. This does not mean that planning for emergency work in future floods in impractical. On the contrary, there are certain broad limits within which such planning can and should be done. Certain problems will be found to arise in any flood, and there are certain fundamental measures that should be applied, and these should be recognized. The problem is to have personnel and equipment in health departments, water works departments, and other units of local and state government, that may be concerned in any way with relief measures or emergency work following floods, trained and available to apply the proper measures in time to be of real value and in accordance with the needs. Any plan devised by a state health department to meet flood emergency problems must be somewhat general and flexible in its provisions. On the other hand, the plans of a local health officer or water works operator to meet the problems peculiar to his locality can and should be more specific in nature.

In brief, the cause of the 1935 flood in New York state consisted of receiving over large areas of the state about a third of a year's normal rainfall within three days' time. The effects of such a phenomenon should be apparent. Physical property damage was enormous as the raging waters poured off the uplands, ripping out bridges, water and sewer lines, and other structures. Hardship and suffering were intensified by the suddenness with which the flood swept through communities in narrow valleys, burying some in rock and debris and making it impossible for residents to make extensive preparations for protecting life and property. As a consequence, there was during the 1935 flood widespread damage to public water supplies, private homes, etc., which created problems quite different in magnitude at least from those encountered during the 1936 flood.

Flood of 1936. The 1936 flood in New York state was occasioned by heavy rains and melting snow throughout the drainage areas of the Susquehanna, Delaware, Mohawk and Hudson rivers, but the flashy run-offs so characteristic of the 1935 flood were greatly lessened. The most serious

conditions were created in communities located along the main rivers where flood levels considerably in excess of those of July, 1935 were reached. For the first time in many years, business sections in Albany, Schenectady and Rensselaer were flooded. High waters in all of the rivers, aggravated by ice jams, prevailed for a week before the flood crests were reached on March 18 and 19. However, the waters rose gradually enough in most instances to permit the orderly evacuation of homes and preparations for the emergency, with the result that to a considerable extent, the confusion that characterized the 1935 flood was lacking. The most serious conditions existed at and below Binghamton along the Susquehanna where all previous flood levels were exceeded, where considerable areas were inundated for prolonged periods, and where public water supplies were affected.

The general plan followed by the State Department of Health to exercise supervision over the public health in the affected regions was similar to that pursued during the 1935 flood, though less extensive due to the less severe conditions. The value of the district-engineering organization of our department was again thoroughly demonstrated and justified. Our district engineers, six of whom were stationed within or in close proximity to the flooded regions, with assistance from our central office were able to reach the affected communities within their districts promptly and give valuable aid in connection with emergency water supply and other sanitation and public health problems. The coöperation extended by local health and water works officials was such that, in the central office, we knew the situation with respect to public water supply difficulties for the most part in advance of their development. While it is not possible to outline in detail all of the steps that were taken to safeguard the health of persons in the flooded regions, there are three that should be emphasized.

1. A month prior to the flood, as is the annual custom of the department, warnings were mailed to all health and municipal officials asking them to be on their guard with respect to possible water supply problems that might arise as a result of thawing snow, swollen streams, and heavy run-off from contaminated land surfaces. In general, water works officials responded to these warning letters and were thus somewhat prepared when the flood occurred.

2. At the first indication of widespread difficulties, the department issued general "boil water" warnings, utilizing the press, radio and other means of publicity. These warnings were picked up locally and rebroadcast with what we believe were effective results.

3. Concurrently our district engineers, supplemented by engineers assigned from our central office, contacted all public water supplies in their districts, ascertained the conditions and arranged to give assistance as needed. Time precludes any discussion of the many forms that this assistance took, but the main objective was to restore water supply failures

as rapidly as possible and assure that the quality of water delivered either through municipal supply systems or distributed from door to door in milk cans or other vessels, was of safe sanitary quality.

4. The other functions performed by our engineers and other personnel of the department was of a miscellaneous nature. The services and facilities of the department were made available to the affected communities and utilized in varying ways. Where local health departments desired to establish typhoid immunization clinics, coöperation and assistance were extended. Nursing service was supplied as requested, and some assistance was given in the general work of cleaning up the region, disinfecting private wells, and work of a related nature. The organizations perfected during the 1935 flood were largely available for the 1936 flood. As a consequence the department's work was considerably reduced. For example, in the 1935 flood the task of organizing and supervising various forces, utilizing C.C.C. camp personnel and relief labor for such work as the disinfection of flooded private wells, the cleanup of basements and streets, or the distribution of water in communities where water supply failures had occurred was assumed to a large extent by the State Health Department. In the 1936 flood these same relief forces, already trained in this work, were prepared to render the same type of service with only advisory assistance from the department. As a consequence, following the 1936 floods the work of our engineers was substantially completed when all public water supplies in the flooded regions had been restored to normal and safe condition, whereas following the 1935 flood the work was continued for more than a month after the disaster, until all flooded private wells had been disinfected, basements cleaned, and the general cleanup of cities and villages fairly well completed.

Water Supply Problems. With respect to emergency public water supply problems during the 1936 flood, a brief summary of the experiences should be of interest.

At Binghamton, flood levels reached the water works pumping station, necessitating shutdown of the filter plant. For about 24 hours the city was able to maintain water service by drawing upon previously stored filtered water. An acute water shortage developed, however, which was met to some extent by utilizing the chlorinated well water supply of the Ansco Company and obtaining about 5 m.g.d. from Johnson City through an interconnection between the two systems.

At Endicott, the wells and pumping station were flooded, and a chlorinated emergency supply was developed from a deep well in West Endicott. At Norwich, flood waters washed out a supply main necessitating shutdown of the filter plant. Temporary hose lines were strung across a bridge, and for a time heavily chlorinated but unfiltered water was delivered. At Granville, the regular water intake became plugged with silt, necessitating the use of an emergency intake. All water delivered, however, was adequately chlorinated.

Dug wells at Valatie were flooded, but a supply obtained from an infiltration gallery and heavily chlorinated was utilized. The water pumping station and wells at Hoosick Falls were flooded, but it was possible to draw upon stored water until operation of the station could be resumed. At Fultonville, one of the municipal wells was flooded, but was discontinued in favor of a supply taken from other wells that were not affected. At Mohawk, the municipal well was flooded, and an emergency chlorinator installation was made. At Delhi, it became necessary to by-pass the filter plant, but all water delivered was heavily chlorinated.

Sewage treatment plants at Oneonta and Canajoharie were flooded to a depth of several feet.

At Rensselaer, the possibility of leakage into the clear well necessitated shutdown of the filter plant for a time, but service was maintained by drawing upon previously stored water.

In Tompkins County, concurrently with the floods in other regions, a severe sleet storm occurred which disrupted power lines with the result that for a time, with the exception of the city of Ithaca, the entire area was without electric power. The Cornell University filter plant was thrown out of operation, but it was possible to obtain water from the Ithaca city supply. At Dryden, a water failure was anticipated but did not occur by reason of three days' storage of water which carried the village over until power was restored.

At Bolton Landing, the turbidity of the water caused clogging of the water chlorinator which was rectified as promptly as possible. At Red Creek, the area surrounding the village well was flooded, and at Central Square, slight flooding of the pumping station occurred. At Candor, a pipe line washout disrupted service to a small section of the village but was restored by means of temporary hose lines between fire hydrants. At Waverly, one break in the mains occurred which was repaired promptly. For a time during the flood Waverly supplied water to Sayre and Athens, Pa. At Nichols, the water chlorinator was flooded and placed out of service for about 24 hours, but "boil water" warnings were continued until safety of the supply was assured.

Many other supplies throughout the various districts were affected in minor ways, but water works operators were alert and kept them in safe condition. Generally, chlorine dosages were stepped up on all supplies as an additional safeguard, and "boil water" warnings were kept in effect in the various communities until safety of the supplies was assured.

Plan of Action. With this somewhat sketchy background of our experiences, it would be appropriate now to consider an answer to the question as to what should be done in an emergency.

With respect to flood emergencies and the functions of an engineering division in a state department of health, it is felt that it should respond in much the same way that we responded to the emergencies of 1935 and 1936 with such improvements in procedures as are possible. We know

that in both the 1935 and 1936 floods, although our work was as prompt and thorough as possible and no cases of illness arose from the flood contamination of any public or private water supply, there were nevertheless several instances where under different conditions an epidemic might have resulted. Between the time that water supplies fail or undergo sudden contamination and the application of the proper corrective measures, lies a definite period during which the seeds of catastrophe may be planted. Engineers of the health department can shorten this hazardous period only in proportion to their ability to get to the supplies affected. But for the local operator or health officer opportunity is presented of reducing this hazardous period to the irreducible minimum. Perhaps some idea can be given with respect to a state health department's plan for flood relief work by outlining the approximate steps which we should take if floods of the magnitude of those of the past two years should again visit the state.

At the first indications of possible floods and before the development of any widespread state of alarm our district engineers would get in touch with local health officers and water works officials, check the condition of the supplies, anticipate possible difficulties, and leave instructions with reference to keeping the department advised as to developments or the need for assistance. Main reliance for the maintenance of the public supplies in a safe condition, for stepping up chlorine dosages, making prompt repairs in case of failures, issuance of "boil water" warnings, developing emergency supplies, and related work would as heretofore be placed upon the local authorities. Much of this instructional work is accomplished by the routine visits made to water supplies at frequent intervals throughout the year. Our district engineers, who are fairly well acquainted with the details of each system within their district, already know what supplies are likely to be affected in case of floods and in time of emergency are able to proportion their work accordingly. Telephone or telegraphic reports would be made by our district engineers to the central office in case of any unusual difficulties. Likewise, reported conditions reaching the central office, many of which would be found to be erroneous, would be transmitted promptly to our field offices, for investigation.

As soon as definite water supply difficulties developed, in practically any community, the local health officer, if in any doubt as to the safety of the supply, would promptly issue "boil water" warnings, using local telephone operators, hand bills, newspapers, and other means of publicity and notifying the department of this action. These warnings would be kept in effect until released by the department after examination into the difficulties and assurance that the supply was in safe condition. If one or two communities only were thus affected the district engineer would give the required assistance.

On the other hand, if it became apparent that many communities were affected or likely to be affected and the press and radio dispatches gave recognition to the existence of a major catastrophe and a general state

of alarm developed, the various forces of the state would be organized and coördinated through the office of the Governor to lend assistance. The State Commissioner of Health would issue general "boil water" warnings to residents of affected areas by means of the press and radio. Instructions would go out to local health officers as to methods for disinfecting private wells and other protective measures. The District State Health Offices would be reinforced by engineering, nursing, and other personnel to be directed from such offices. The central office would become a clearing house for information and instructions to and from the field, and within about 24 hours all public water supplies in the affected regions would have been visited by a department engineer and steps taken to restore service, insure proper treatment, develop an emergency supply or perform such other tasks as might present themselves.

No other work would be undertaken by our engineers until the public water supplies were under control. Thereafter until the emergency passed they would keep in close touch with the water supply situation and give such assistance as might be possible or needed on general sanitation matters. They would make their services available generally to local health officers and local officials in all the affected communities. Where relief labor forces were available, they would assist in the organization of the work of disinfecting private wells throughout the flooded sections. They would examine into sources of water supply used by emergency water distributing details and into sources of milk supply reaching the communities, and in hundreds of ways give assistance and guidance to local officials in the handling of the many problems of a sanitary nature which invariably arise following such catastrophies. District state health offices supplied with additional nurses and medical officers from the central office or from other districts would extend assistance to local health officials in the establishment of typhoid immunization clinics and in other medical and nursing phases of the relief work.

Thus in some such fashion our Department would expect to function. Public water supplies would be given first consideration and no effort made to moderate the general state of alarm until their safety was assured. Thereafter, every effort would be made to give assurance to flood sufferers that conditions were under control and that many of the conditions which contributed to the general state of alarm such as silted basements, decomposing stocks of vegetables, streets littered with débris, etc., actually have no particular public health significance. With public water supplies under control, efforts would be made to relieve the worries of the flood sufferers as much as possible, at the same time giving all possible assistance and encouragement in the general cleanup work and the restoration of conditions to normal as rapidly as possible.

From experiences in New York State it is apparent that any effective plan for providing for emergency relief service in time of floods must revolve around local health officers, local water works operators and

superintendents, and other local officials. The state can supply assistance and guidance, but the real responsibility and opportunity for service rest upon the local officials. The problem then is to train these local officials in such a way that they will become equipped and able to respond properly to any emergency. When local officials are thus trained and equipped, the state can have reasonable assurance that in an emergency every precaution and corrective measure within the limits of human knowledge will be undertaken. Beyond this, there seems to be little that can or need be done.

This training of local officials to respond to emergencies can be accomplished and aided in innumerable ways. A good starting point is the establishment throughout the state of intelligent, energetic, and competent local health officers and water works operators. For the most part, New York State is already so equipped. Health officers can be trained over a period of years so that they will know whether or not in any given circumstance they should issue a "boil water" warning; but they can know this only by being acquainted with the details and characteristics of the supply under their jurisdiction. The presence of *B. coli* in a water supply is not always sufficient to warrant a "boil water" notice. There are many small supplies derived from shallow springs located on well protected areas that will show *B. coli* at intervals, especially following rains, the contamination being due entirely to superficial ground water and the remedy being the installation of chlorination. However, such contamination, unless the opportunity is present for its being of human origin, is not of much significance. In any event, if the presence of such contamination is more or less a normal condition, there seems to be no justification for issuance of a "boil water" warning just because neighboring communities may be involved in water supply difficulties. However, much could be said about "erring on the side of safety." Health officers who are quick to issue "boil water" warnings in flood times to cover a condition that is more or less normal to the supply would follow a better procedure if they were to direct their energies toward obtaining in normal times continuous chlorination of the supply so that the necessity of issuing frequent and repeated "boil water" warnings would be obviated. Health officers, furthermore, can be trained to keep in close touch with local water supply situations, and notify the department of any changes or need of assistance. Prompt reports to the State Health Department by local health officers in times of emergency, giving exact information as to local conditions, are essential if the state forces are to function properly; otherwise much valuable time will be lost in following false leads and separating the communities in actual need of assistance from those that may require none.

Local water works officials can be similarly trained over a period of years, and this should be a constant endeavor of a state health department. It would be impossible to outline in detail all of the possible problems that might arise among the water supplies of a state during a flood. Certain difficulties are more apt to develop at one place than another, and it is the

responsibility of the local operator or superintendent to anticipate these possible emergencies in all their details and be prepared to meet them. To do less than this is to fail to fulfill the obligation of trust imposed upon him.

The importance of each local operator becoming fully acquainted with the details of the system under his care and becoming trained so that he will know what course to follow during an emergency is illustrated to some extent by certain experiences and problems presented below.

In one instance, knowledge of the existence of a duplicate supply main across a river would have prevented shutdown of a filter plant. In another case, knowledge of the existence of a second inter-connection between two adjoining cities would have made it possible to obtain, during an acute water shortage, sufficient water to meet the reasonable needs of the people. In another instance, improper closing of a valve and failure to discover this for a period of more than 24 hours resulted in wastage of filtered water to a stream so that service was not restored to consumers. In one community, an emergency pumping station was set up to supply water from a polluted stream without providing the safeguard of chlorination. In another community a filter plant operator maintained normal alum dosage even though the turbidity of the raw water increased a hundred fold, with the result that very turbid water was delivered at a time when a clear sparkling water would have done much to strengthen the morale of a weary people. Many communities were without preparation for installation of emergency chlorination equipment, with consequent delay when it became necessary to arrange for the installation of such equipment.

When all operators are able to anticipate the conditions and problems likely to develop and are able to take the proper and logical steps to overcome them, and when the villages and cities become sufficiently impressed to make new investments in water supply improvements and equipment that will prevent the development of or lessen the seriousness of an emergency, we may have reached our goal in our efforts to make floods safe from the public health standpoint. Until then hazards of varying proportions will continue to arise as the result of public water supply difficulties in times of flood.

For an operator to prepare himself to handle emergencies properly requires a detailed and thorough knowledge and understanding of both public health and hydraulic aspects of modern water supply practice, in addition to the details and characteristics and weakness of the system that he operates. Chlorine dosages are not apt to be carefully controlled, unless the operator himself is aware of the potentialities of laxity in operation. Chlorinators for one reason or another are subject to breakdowns. An operator thoroughly imbued with the sense of his responsibility will see to it that he has a reserve machine or at least reserve parts on hand and in operating condition. Where a pipe line crosses a stream is a vulnerable point that should be recognized and plans formulated to restore service to the isolated sections of the community in case of a washout. The operator

in planning against this eventuality should carry his plans to the point, for example, of knowing the distance between the two fire hydrants which he would connect, and where he could quickly obtain temporary hose lines for such connections. If he were properly trained and imbued with public health procedures, he would have a supply of chlorine compound on hand to use in disinfecting the hose before placing it in service. He would know all valves and their functions, within the plant and out on the distribution system, so that there would be no delay if necessity dictated their operation. In short, he would know what to do, how to do it, and would have the equipment and implements necessary for the work readily available.

There are numerous and intricate situations that a water works operator or health officer is apt to meet during floods, the details of which cannot be outlined here. How far a health officer should be prepared to go in safeguarding the quality of water in his community during a flood emergency is well illustrated by the procedure followed by the health officer of one city in the summer of 1935.

When the water supply failed due to failure of a dam and washout of two supply lines leading to the filter plant, he immediately issued "boil water" warnings. He busied himself with the problem of getting an emergency source of supply to the filter plant as it would take several days before the washouts could be repaired. This was accomplished by establishing two emergency pumping stations and laying the necessary temporary lines. He had previously obtained analytical records on some of the large wells throughout the city. As a consequence, when it became necessary to organize a water delivery service by trucks and tank wagons, which was done under his direction, he was able to select a source of supply which was safe. Nevertheless, he recognized the opportunities for contamination of the water in handling and the possibility of the wells becoming contaminated, notwithstanding the previous satisfactory analyses, due to increased draft upon them and their location with respect to some of the city sewers. He accordingly sent printed instructions out with water deliveries so that people would be warned to boil all water thus delivered. He checked up on the sources and quality of various bottled water supplies that were reaching the city. And when it became possible to resume operation of the filter plant and restore public water service he ordered the maintenance of a high chlorine dosage and residuals. He repeated his "boil water" warnings and made tests for residual chlorine throughout the distributing system until he was assured that properly chlorinated water had reached all parts of the system. Even then he did not lift his "boil water" orders. He collected samples from many points throughout the system, and for more than two weeks following restoration of water service he continued to get *B. coli* in some of the samples. It was not until he had secured three successive series of analyses free from *B. coli* that he was willing to lift the "boil water" orders. In this particular case the question might be raised as to the necessity of continuing the "boil water" warnings

beyond the time when he found positive chlorine residuals throughout the distribution system. There were three things that influenced the health officer in his decision. First was his knowledge that when the water supply suddenly failed back siphonage conditions existed in hotels and buildings throughout the city with the definite probability that the water mains had become dangerously contaminated with sewage. Second was his lack of confidence in the orthotolidin test, due to the possibility of nitrites and manganese in the water, with the consequent feeling that residual chlorine tests made at points throughout the system might be in error. Third was his desire to err on the side of safety.

When all health officers have been trained to the point that they will respond to an emergency along much the same lines as those described; when water works operators are similarly trained to the point that they can and will do the things required of them promptly during an emergency and have the essential equipment at hand for their work; and when the municipalities themselves have made every improvement that can reasonably be anticipated as needed for the protection of their public water supplies in case of floods, we shall be well along on our road of providing for the maximum protection to people affected by flood catastrophies. In any general plan, therefore, developed toward this end, energies ought to be directed along the lines indicated. In New York State we are trying to do this by our routine contacts with local health officers and water works operators and officials, by the training given at schools for water works operators, and by such other means as are found possible. In conclusion the thought occurs that if every water works operator and local health officer in New York and in other states could have the opportunity of hearing the points and lessons brought out by the discussions in this symposium, much progress would be had immediately in the preparations which ought to be in normal times against contingencies of the future.

PUBLIC HEALTH ASPECTS OF THE FLOOD OF MARCH, 1936 IN PENNSYLVANIA.

BY W. L. STEVENSON.*

[*Read September 23, 1936.*]

The floods of March, 1936 were wide-spread throughout Pennsylvania, affected large number of people and wrought great property damage. The havoc was greatest in the western and central counties. It was less in the southern, eastern and northern counties.

These floods adversely affected public water works supplying 200 communities and about 2 000 000 consumers. Of these, 1 500 000 dwelt in the Ohio River basin. Three large water works serving Pittsburgh and its environs have 1 000 000 consumers. In 250 communities private water supplies were contaminated by flood waters. In 350 communities, dwellings were inundated. All of these three conditions were coincident in many towns.

Notwithstanding this grave menace to public health there were no epidemics of reportable disease in the flooded area and only from four to six cases of typhoid can indirectly be connected with the flood.

This unexpected outcome of the worst wide-spread flood in Pennsylvania's history was the result of a number of factors; including, the preparedness of the State Health Department and the faithful zeal and skill of its employees, the splendid coöperation of physicians, nurses, municipal officials, water works officials, the public, and the American Red Cross with the State and Federal agencies engaged in safeguarding health and prevention of disease in flooded areas.

On February 27, 1936, the first water works was inundated at Parkers Landing on the Allegheny River. This was caused by an ice jam on the river below. Restricted use of water during the shutdown of the filter plant conserved filtered water in storage and allowed limited service in the town, except in the high level area. The people in that section were supplied with drinking water from a nearby unaffected water supply hauled in Highway Department tank wagons. As soon as the flood waters receded the water works were cleansed and put back in service with heavy chlorination.

But ten days before this water works was flooded, the Department of Health had developed a definite plan of action and coöperation to meet the flood emergency when it should arrive. The heavy blanket of snow covering the earth, the deeply frozen ground and ice-bound rivers made it self-evident that rising temperature and rainfall would cause floods, probably serious ones.

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Therefore, the Secretary of Health, Dr. Edith MacBride-Dexter, on February 17, 1936, issued to every local board of health in Pennsylvania, a notice of warning and instructions as to its duties when the flood came. The Department's County Medical Directors were given instructions as to their special duties in flooded second-class townships (which have no local boards of health). District Engineers were directed to contact officials of water works whose plants might be endangered by flood waters, and they were told to coöperate with them in safeguarding measures such as storing the largest possible volume of purified water and erecting emergency barriers against flood waters at low-lying pumping stations and filters.

An arrangement was made with the State and Federal Hydrographers for prompt notification as to rising river stage and flood forecasts, and with the State Highway Department and National Guard of Pennsylvania for use of their motorized water tanks to haul drinking water into stricken areas. Three of the Department's mobile laboratories were specially equipped and manned to be sent into stricken areas for bacteriological analysis of drinking water. The Medical, Nursing and Biological Products Bureaus of the Department were organized for swift mobilization. The Works Progress Administration of Pennsylvania was requested to obtain approval in Washington of a State-wide project to furnish labor, trucks and tools for swift clean-up after the flood waters receded.

The employees of the Bureau of Engineering were relieved of normal duties, and they were engaged in emergency flood work from before the floods actually struck until the clean-up was well underway. This included the staff* in Harrisburg, the seven District Engineers* and their assistants and all special corps.

The Surgeon General of the U. S. Public Health Service graciously offered assistance to the department. R. E. Tarbett, Chief Engineer, and nine Assistant Engineers reported in Harrisburg on March 20, 1936, and soon thereafter were actively at work in the field rendering most valuable and helpful assistance.

During the floods, 281 persons were on duty in or for the Bureau of Engineering. This includes the 10 U. S. Public Health Service Engineers, 36 federal employees of the W.P.A. sealing coal mine work, 106 white collar W.P.A. men on the sanitary inventory in the Wilkes-Barre district and 64 Health Department Health Officers.

River Stage and Flood Forecasts. In Pennsylvania, stream gaging was begun in 1897 by the U. S. Geological Survey and in 1907 taken over by the former Water Supply Commission of Pennyslvania. Since 1931, a coöperative agreement has been in force between the Department of Forests and Waters and the U. S. Geological Survey relative to stream gaging. This work is under the joint charge of Charles E. Ryder, Chief

*H. E. Moses, Assistant Chief Engineer and Staff Engineers Daniels, Drake, Hoffert, and Siebert, also District Engineers Barrick, Fletcher, Freeburn, Gorman, Matter, Morgan and Young.

Engineer, assisted by Ralph H. Hosmer, Hydrographer, and J. W. Mangan, District Engineer, U. S. Geological Survey. There are 99 stream gaging stations in Pennsylvania.

In preparation for the flood, arrangements were made with certain gage readers frequently to report river stage and, when the floods were developing, to wire or phone to Harrisburg the changing river stage, so as to keep the hydrographers as fully informed as practicable. These data were at once given to the Chief Engineer of the Health Department who in turn immediately informed the relevant District Engineer, who in his district was obtaining river stage at water works and other points where there were no gaging stations and relaying it back to Harrisburg to augment the data of the hydrographers.

In a similar way flood forecasts of the State hydrographers and of the U. S. Geological Survey and Weather Bureau officials were swiftly sent back and forth.

This arrangement made it possible for the District Engineers to forewarn water works as to rising river stage and probable flood height and time of cresting and to be prepared to give aid and assistance to water works operators. The forecasts were reliable and substantially assisted in guiding emergency work at flooded water works.

Public Water Works. Too much commendation cannot be given to the officials and operators of water works in the flooded areas. They showed skill, zeal and fidelity to duty, working long hours under the most adverse, and sometimes hazardous conditions.

Some low-lying pumping stations and filter plants were barricaded to hold back the flood waters. Chlorinators were at some places moved to higher elevations. Maximum possible volume of purified water was maintained in storage to tide over the shut down of the plant. In some cases, emergency connections were laid with adjacent mains of another water supply. In other cases, fire engines and hose were used to transfer water from one system to another whose supply was exhausted. There were instances of most neighborly action where one community continuing on restricted water use in order to permit serving part of its water supply to a nearby town.

"Boil Water" Warnings. Never before in Pennsylvania was there such an imperative necessity that very large numbers of people should boil their drinking water as a disease-prevention measure. It was decided that the warning must be universal. To have stated that certain water supplies remained safe but others should be boiled would have resulted in confusion thrice confounded. Therefore, just before the floods, the warning was issued to boil all drinking water in flooded areas. This was continued all through the flood period by newspapers and radio. Local officials did likewise. In some communities automobiles with amplifiers were also used to carry the "Boil Water" message. Printed notices were posted by municipal officials. The result was that the people in the flooded areas

were thoroughly aroused, and it is verily believed, in larger percentage than ever before, they did boil their drinking water.

Naturally some water purveyors, who during the floods had maintained service of pure water, were aggrieved because these warnings created public distrust of their safe supply. But it is now believed that the universal warning to "boil all drinking water" was fully justified by experience and that it played a substantial part in prevention of water-borne disease.

Furnishing Water to Stricken Towns. Flood stage reached such unprecedented heights along many streams that, regardless of everything done to protect them, water filters and pumping stations were inundated and put out of service. Also, notwithstanding cutting off industrial use and reduction of domestic consumption, there were many cases where the water in storage was insufficient to serve even limited quantities of drinking water to the consumers while the water works were being put back in operation after the floods receded. In such cases, drinking water was hauled in chlorinated motorized water tanks from the nearest safe available public supply.

Throughout the flooded area this was generally done through the coöperation of the State Highway Department who made available every water tank they could spare to the Health Department. The National Guard of Pennsylvania likewise furnished their Army type tanks for use in communities within quick reach of their base at Mt. Gretna (near Harrisburg). The Civilian Conservation Corps did valient service in hauling drinking water in cans on their trucks. At some places, emergency mains were laid to connect adjoining water systems, and in other places, fire engines and hose were used to make such connections.

The most unusual delivery of water in stricken cities was made by tanks of the Atlantic Refining Company. For awhile it appeared that the water supply of Pittsburgh would be exhausted before the flooded pumping stations could be put back in service. Had this occurred, over a half million people in that great city would have had no public water to drink. By heroic work on the part of the city officials and workmen this did not happen.

However, as soon as the Atlantic Refining Company knew of the threatened tragedy they immediately cleansed sixty of their most powerful motorized tanks, manned them with drivers having the best "safety" records and started them on the journey across the state from Philadelphia to Pittsburgh. State Highway Patrolmen acted as pilots over the roads and over many detours because of washed out highways and bridges. Outside of Pittsburgh these tanks were filled with pure water; then they proceeded on their way. Only a few were needed in Pittsburgh itself but they at once served outlying communities whose water supply had failed.

Then the water supply of Harrisburg approached exhaustion, because the flood had overtopped a dike around the filter plant on an island in the

Susquehanna River. When the flood waters receded, this dike had to be breached and the inundated pumps and filters cleansed and repaired. Meanwhile, the filtered water in the storage reservoirs was being used up notwithstanding its being augmented from two neighboring supplies and the zealous efforts of the city officials to restrict consumption.

The critical water condition in and near Pittsburgh was then passing, so the Company's fleet of tanks was rushed back to Harrisburg. Streets were selected between the reservoir and a public water supply across the river, and over them at high speed these tanks were rushed back and forth. A policeman or National Guard soldier was stationed at every street intersection to control traffic. In this way the water in the reservoir was gradually built up until the pumps and filter plant were put back in service. The expense of maintaining these tanks was wholly borne by the Atlantic Refining Company.

General Public Health Work. The Health Department's County Medical Directors received and distributed biological products in the flooded areas and superintended establishing and providing medical service for emergency hospitals and first-aid stations. The Department's nurses manned emergency vaccination stations, helped care for refugees and warned all of the people in the flooded area with whom they came in contact concerning boiling drinking water and not eating contaminated food. The Department's Division of Supplies and Biological Products distributed medical and first aid supplies and typhoid vaccine and tetanus antitoxin.

First and Second Floods. Along most streams there were two separate floods. The first was caused by rising stage breaking up the ice cover and the formation of ice jams. The second flood occurred soon after the ice had gone out and was primarily caused by rising temperature, melting snow and ice and heavy rainfall on the catchment areas.

Generally, throughout the flooded areas, the water of the first ice jam floods was dirtier than during the second floods. Also, the deposits left by the first flood contained more organic matter than did the deposit left by the second and larger flood. In many cases, this second deposit resembled silt or detritus, which when dried was blown about like dust by high winds.

It is probable that the first flood scoured out and carried away sludge deposits of organic origin in the streams. This was fortunate because the first floods inundated communities to a relatively slight extent as compared with the much higher river stage of the second flood.

Restoration of Public Water Supplies. As the flood waters receded, the most urgent work was rehabilitation of flooded public water works. The municipal and company officials in charge of such water works did an outstandingly good job in cleansing and repairing their water works. The larger ones having ample personnel and equipment did this work mostly on their own initiative, thus leaving the Health Department Engineers more

time to assist the smaller and weaker water works. The problem was, not only to restore service of water as soon as possible but of even greater importance that the water served should be safe and pure. This necessitated the most thorough cleansing and sterilizing of the flooded parts of the water works and then applying heavy doses of chlorine to the water when the filters were put back in operation, in order to send through the mains water carrying a good chlorine residual.

Valuable service was rendered by the Wallace and Tiernan Company in sending their experts provided with chlorinators and repair parts to flooded water works where such service was needed. The experts of this company worked with both water works operators and Health Department Engineers. In many cases this permitted earlier resumption of proper chlorination than would have been otherwise possible.

After the water works were rehabilitated, thoroughly cleansed and service of water was to be resumed, samples were collected and promptly analyzed in the Health Department's mobile laboratories in the field. Some samples were sent to the Department's main laboratory in Philadelphia and others were analyzed in water works laboratories. It was not until the resumed water supply was found to be safe that the Department discontinued the warning to boil all drinking water in the territory served by the rehabilitated water works.

Cleansing Private Water Supplies. Thousands of private sources of drinking water were inundated and contaminated by the flood waters. These consisted chiefly of dug or drilled wells and some springs. As far as possible, the public depending on these private sources of water were continuously warned that such sources should not be used but if it were absolutely necessary so to do, because no other water could be obtained, then all such well water must be thoroughly boiled before use.

Labor promptly furnished by the Works Progress Administration made it possible to assist householders to cleanse and disinfect private wells. The procedure was as follows:—mud and débris were removed from the top of the well and its immediate surroundings, then the water of the well was pumped to waste for a considerable time. After this, a strong solution of chloride of lime was poured into the well, and it was allowed to stand at least 24 hours and generally 48 hours or more. Then the chlorinated water in the well was again pumped to waste until it did not show residual chlorine to orthotolidin, when a sample was taken for analysis in the Health Department's nearest mobile laboratory. Householders were warned to continue boiling this water even though it had been sterilized, until the results of analysis of the sample showed that the water was again potable.

As expected, it was found that many wells which had been inundated by the flood waters were either poorly constructed or improperly located so that they did not yield a safe water before the flood, and therefore, even though sterilized, the water was not safe afterward. In such cases, the

householder was so advised, and if the fault was of construction only, was told how to correct the structural defects.

Clean-up of Town Sites. When the flood waters receded from inundated built-up communities, the amount of clean-up naturally depended upon the depth of inundation. In almost all cases, cellars were left in a flooded and dirty condition; in many cases this also applied to the first floor of dwelling houses and to less extent, even the second floor.

As was stated before, the kind of deposit varied; that left from the first or ice jam flood was generally more dirty than from the second flood. There was also variation between the conditions existing along the banks of a river and farther back in the town site. Generally, within the town site the deposit included garbage and also night soil where there were flooded privies. Throughout such inundated towns, there were all kinds of débris and rubbish swept down the rivers with the flood waters or coming from the town itself.

Here, again, the labor, trucks and small tools made available by the Works Progress Administration were of outstanding value in expediting the clean-up of inundated towns. Without such help the citizens of a flooded town would have been thrown on their own resources, and the clean-up would have been delayed for a long time.

Lime. In the aggregate, enormous quantities of lime and chlorinated lime were used by municipalities and water purveyors in the clean-up after the floods. The Health Department, realizing that many municipalities, especially the smaller ones, would not be able promptly to obtain these necessities, early in the flood period placed orders for delivery to strategic points in the flooded districts of quicklime, hydrated lime, and chlorinated lime in bulk. From these stations, delivery was made to municipalities in need, under the direction of the District Engineers.

Quicklime and hydrated lime were generally used in cellars and around dwellings. Chlorinated lime was generally used for disinfecting contaminated private sources of drinking water, flooded privies and in dwelling houses above the cellars.

J. R. Hoffert of the Bureau of Engineering Staff handled this emergency work including delivery and distribution of about 950 tons of lime and 115 000 pounds of chlorinated lime.

Temporary Latrines. In unsewered communities, where privies were washed away by the floods, it was essential that temporary sanitary latrines should be provided as soon as possible to minimize promiscuous defecation upon the surface of the ground. This work was facilitated with labor furnished by W.P.A. Also, in the early days some permanent privies were built under the federal work relief "Community Sanitation Project."

Flooded Coal Mines. A unique problem was created by the flooding of coal mines in Pennsylvania. The outstanding instance was in the Pittston-Duryea area where about 9 billion gallons of flood water poured into several interconnecting anthracite coal mines submerging the mine

pumps and throwing out of employment about 5 000 miners with 15 000 dependents. The operators of these flooded mines had other mines capable of supplying all their customers. The companies estimated that it would cost them over $1 000 000 to recondition the mines if they were dewatered.

This state of affairs meant, if the mines were not dewatered and mining resumed, that the communities dependent upon these mines for support were faced with poverty and the burden upon relief funds would heavily increase. Also, the unmined coal would be lost in perpetuity. Furthermore, if the hydrostatic pressure of the water would cause the barrier coal to fail, then many other coal mines in this valley would be inundated and ruined.

Soon after the mines were flooded, Governor Earle made personal inspection of conditions at these mines, determined that a dire emergency had been created and that the State should finance dewatering, provided the coal operators would furnish all labor in connection therewith and afterwards recondition the mines and resume mining operation. They agreed to do so. The work was placed in the Department of Health with the Department of Mines coöperating. The General Assembly in Special Session appropriated $700 000 for dewatering.

As rapidly as possible, 18 powerful motor-driven pumps were delivered and necessary power lines and pipes installed, and the dewatering began on June 12, 1936. Up to September 15, 1936, 4 300 m.g. of water had been pumped out of the mines in the Pittston-Duryea area.

Meanwhile, other smaller coal mines inundated by the March floods have been dewatered, reconditioned and mining resumed.

Why No Epidemics?

While every possible effort was made to prevent disease outbreaks during the floods the officials of the State Health Department prepared to meet that phase of the emergency. It was therefore, a great relief when a reasonable time elapsed after the floods and no reports came into the central office of any epidemics of reportable disease from the flooded areas.

Among the reasons may be enumerated the following:

(1) The zeal and skill of water works officials and employes to safeguard their plants, to serve pure water as long as it lasted, to quickly rehabilitate flooded parts and only resume service when assured that the supply was safe.

(2) The quite general practice of the public in the flooded area to boil all drinking water of questionable character.

(3) The cleansing and sterilizing of flooded private sources of drinking water and the rapid clean-up of inundated communities.

(4) The scouring out of organic deposits by the first and smaller ice jam floods and the enormous dilution of the second and major flood.

(5) The preparedness of the State Health Department with definite plans, the fidelity of its public health workers, and above all the whole-hearted coöperation of the public with all agencies concerned in the prevention of disease.

Flood Prevention.

In the history of mankind it has repeatedly occurred that it takes a calamity to demonstrate to the public facts which a few men of vision knew and preached for many years but the people would not heed their arguments.

For years engineers and public spirited citizens have advoeated flood control works but as we read in the Rubaiyat

> Myself when young did eagerly frequent
> Doctor and saint, and heard great argument
> About it and about; but evermore
> Came out by that same door wherein I went.

As soon as the shock of the flood crest passed, a demand was made by the public in the stricken areas that Government should build works to prevent floods. The Congress and State Legislatures heeded the call, and this may result in the carrying out of measures to reduce flood height. Nevertheless, water works and public health officials must still be prepared for floods in the future even though maximum stage may be reduced through flood control works.

Lessons for the Future.

There has been a definite trend toward using relatively clean upland sources of public water supply served by gravity instead of pumping water from a river more or less polluted, subjecting it to elaborate processes of purification, and again pumping it to storage reservoirs whence it returns by gravity to the town along the river.

The March 1936 floods in Pennsylvania put out of service about 100 water works having parts subject to inundation. Of them, pumps were flooded in 60 per cent of the cases; chlorine apparatus in 35, clear wells in 23, filters in 13 and chemical feed apparatus in 13 per cent.

On the other hand, flooded communities whose public water supply was derived from impounded upland sources not only, generally, had water all through the flood, but as the flood receded there was ample water to use for flushing and cleansing purposes.

Where water works are situated at such an elevation that they can be inundated by floods, where practicable to do so, all vital parts should be placed above maximum flood height or safeguards erected so that during future floods they may continue in service.

Likewise, the flood demonstrated that some water works have insufficient storage for filtered water to tide over a shutdown of pumps or filters. Where practicable, storage should be increased.

Public health workers have long advocated that built-up communities ought to have piped public water supplies instead of the citizens depending upon private wells or springs on their properties, so often subject to contamination through the disposal of human excreta in the nearby cess-

pool or privy. The floods demonstrated the soundness of this doctrine through the large number of flooded private water wells and the great task swiftly to cleanse and disinfect such wells.

Finally, the flood demonstrated the value and need for well organized and equipped state and municipal health departments and the outstanding importance of well designed and constructed water works manned by trained, skilled and faithful operators continually,— day and night, in fair weather and foul, when all is well or under the most adverse circumstances — to furnish to the consumers safe, wholesome and palatable drinking water.

DISCUSSION.

E. R. Cox.* The following procedure was followed in preparing the furnace-oil trucks used for hauling drinking water during the March flood in Pittsburgh and Harrisburg, Pa.

These trucks were previously in furnace-oil service and not gasoline service.

1. The tanks were steamed, with low pressure steam for 15 to 20 minutes.
2. Tanks were thoroughly scrubbed with a high-pressure hot-water steam jet. Hot water and steam were furnished by a "Hi-pressure Jenny." (This type of equipment is often used for building exteriors.)
3. Tank was filled to overflowing with city water and then drained off through the tank lines.
4. Tank was filled to within 6 in. of the top with city water to which was added 2 ounces of chloride of lime.
5. The chloride of lime was permitted to remain in the tank for the first 100-mile travel of the truck at which time all but 200 gal. were drained off. The 200 gal. were allowed to remain in the tank until the trucks had reached their destination.
6. The tanks were then drained and thoroughly flushed with a fire hose. They were then ready for the service of hauling drinking water.

If these trucks had been formerly used in gasoline service, this procedure would have been preceded by loading the tank with unleaded gasoline within 6 in. of the manhead; running the truck for about five minutes and then draining the gasoline off.

* Vice President, Atlantic Refining Company, Philadelphia, Pa.

PUBLIC HEALTH ASPECTS OF THE FLOOD OF MARCH 1936 IN MASSACHUSETTS.

BY ARTHUR D. WESTON.*

[*Read September 23, 1936.*]

Any condition, which like the great flood of 1936, seriously threatens the purity of water supplies and interferes with the sanitary removal and disposal of the wastes of human activity must be considered a challenge to the environmental control of disease and a real menace to the public health. Those of us who are engaged in environmental health control work in the state of Massachusetts hope that we have profited by our experiences during that memorable week of March 15, 1936. Should we suffer a recurrence of such conditions, in spite of the predictions of authorities on the theory of probability who state that such a flood probably occurs but once in a thousand years, we expect because of our experience during the past year to be equipped to combat the menace more effectively than before.

The public health aspects of a serious flood as an engineer engaged in environmental control work sees them are:

1. Danger from the pollution of water supplies.
2. Danger from the failure of water supplies and resort to supplies of questionable quality.
3. Danger from improper living conditions necessitated by the assembling of large numbers of refugees in armories, halls, etc., often with inadequate sanitary facilities.
4. Danger of contamination of milk and other food supplies by inadequate safeguards, improper handling or contact with polluted matter.
5. Danger from unusual exposure, from immersion and from general wet and inclement living conditions.
6. Danger from physical exhaustion.
7. Shock to mental equilibrium by circulation of false and baseless rumors by self-appointed experts who without the least justification advise the population of the need of wholesale inoculations, of imaginary dam failures, water supply shortage, epidemics, etc.

We, as sanitary engineers, have tried our best successfully to combat all of these menaces and feel that except against the rumor spreader we have built reasonably strong fences to protect the public health at times of flood in Massachusetts in the future.

Cause and Magnitude of Flood. The abnormally heavy rainfall that occurred over large areas of the watersheds tributary to Massachusetts streams during a period of abnormally high temperatures when the ground was frozen and covered with snow of high water content resulted during the week of March 15, 1936, in the greatest recorded run-off and caused one

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of the strongest threats to the purity of our public water supplies that has ever been experienced by the Massachusetts Department of Public Health.

Records made available to the Massachusetts Department of Public Health show that the precipitation for the month of March 1936, on most of the drainage areas seriously affected by floods, was in excess of 6 in. At Pinkham Notch, in the White Mountains, a total precipitation was recorded for the month of March of 23.86 in. To our knowledge this figure is the greatest monthly precipitation ever recorded in New England by an approved gage. Records of 9, 10 and 11 in. of rainfall during March 1936 were common throughout Massachusetts. Much of this precipitation occurred during the weeks of March 8 and 15, the greatest intensity being recorded between March 9 and 23, inclusive. On those streams on which the greatest damage was done, there were two peaks, one on March 14 and 15 and the other on March 19 and 20.

Table 1 shows a comparison between the normal rainfall at eight widely scattered stations with long term records and the rainfall of March 1936 at these stations:

TABLE 1.— RAINFALL FOR MASSACHUSETTS AS A WHOLE AS DEDUCED FROM RECORDS AT EIGHT RAIN GAGING STATIONS.

	Normal Monthly Precipitation — Inches.	Precipitation 1936 — Inches.
January	3.81	7.28
February	3.56	2.85
March	3.98	8.13
Total	11.35	18.26

Table 2 is presented to show the great precipitation in the principal river valleys throughout the month of March 1936 and, by comparison with Table 1, the relation of rainfall throughout the state as a whole and at the rain gaging stations in the river valleys in question.

Not all drainage areas have the same run-off characteristics and, accordingly, the run-off from some areas may be very rapid and from others very slow. This is particularly true of the drainage areas of certain Massachusetts streams, viz., the Housatonic, Connecticut, Merrimack and Charles, the peak flows of which during March 1936 are shown in Figures 1–4.

The Housatonic had two peaks of about equal intensity and of reasonably short duration. The Connecticut also had two clearly defined peaks, each of longer duration than those of the Housatonic, but each peak was different in intensity. The Merrimack peaks were of much shorter duration than those of the Connecticut, while the flow of the Charles was slower in reaching its peak and slower in receding than for any of the other

TABLE 2.— PRECIPITATION — MARCH, 1936.

Date, March.	Charles River.		Merrimack River.		*Saco and Merrimack Rivers.	Blackstone River.		Connecticut River.		
	Waltham.	Millis.	Lawrence Experimental Station.	Groton.	Pinkham Notch, N. H.	Kendall Reservoir.	Whitinsville.	Greenfield.	Williamsburg.	Westfield.
1	.35	...	...	...	.02	...	...	...	...	...
2	.30	.45	.27	.33	...	.36	.36	.20	.14	.28
3	.02	.22	.12	.23	.25	.09	.16	.1	...	...
4	.19	...	...	...	.01	.01	...	.04	.03	...
5	...	.14	.02	.36	T	.25	.17	.28	.19	.29
6	...	...	.26	...	.03	...	...	...	...	...
7	...	...	...	...	...	...	...	...	...	...
8	...	...	.02	.01	...	...	...	.08	.08	.03
9	.01	...	.12	.16	.86	.10	T	.12	.20	.06
10	...	...	...	...	.07	.02	.10	...	...	.03
11	1.48	2.29	1.05	1.97	.69	3.05	2.55	2.11	2.71	3.02
12	.67	.65	.45	.54	6.46	.24	.46	.56	.30	.16
13	...	...	...	...	.63	...	...	...	...	.04
14	...	...	.06	.02	.08	.03	...	.14	.01	...
15	...	...	...	...	...	T	...	...	...	...
16	...	...	...	...	.86	...	...	.08	.01	.04
17	.11	...	.02	.29	.44	1.00	.95	.32	1.40	1.00
18	2.32	3.06	1.65	2.59	6.27	4.39	3.50	2.17	1.77	2.02
19	...	...	...	.09	4.05	.04	...	.11	.09	.06
20	.17	.20	...	.33	.05	.40	.50	.28	.90	.52
21	.50	.79	.92	.70	1.33	.50	.51	.56	.28	.42
22	...	...	...	...	.64	...	...	...	...	...
23	...	...	...	...	.04	...	...	...	...	...
24	.32	.26	...	.40	...	.28	.27	.20	.39	.37
25	...	...	...	...	.28	.03	.03	...	...	.02
26	...	...	...	...	.01	...	...	...	...	.02
27	1.02	1.01	1.12	1.10	.38	1.02	1.02	.95	1.05	1.03
28	...	...	...	...	.34	...	...	...	...	...
29	...	...	...	...	.01	...	...	...	...	...
30	...	...	...	...	...	...	...	...	...	...
31	...	...	...	...	.06	...	...	...	...	...
Total	7.46	9.07	6.08	9.12	23.86	11.81	10.62	8.20	9.57	9.42

* This extraordinary record apparently covers a small area. 25% greater than any nearby gage.

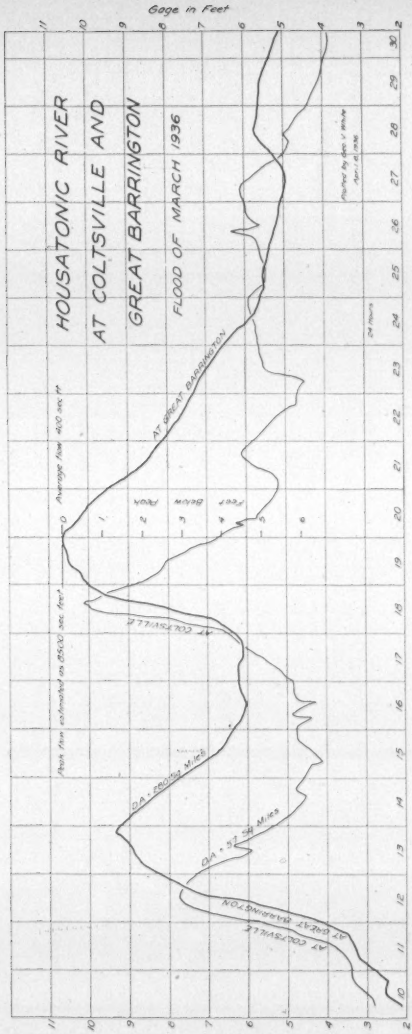
HOUSATONIC RIVER
AT COLTSVILLE AND
GREAT BARRINGTON
FLOOD OF MARCH 1936
Gage in Feet
Average flow 400 sec ft
Peak flow estimated as 8500 sec feet
Feet Below Peak
AT GREAT BARRINGTON
AT COLTSVILLE
D.A. = 280 Sq Miles
D.A. = 57 Sq Miles
AT GREAT BARRINGTON
AT COLTSVILLE
24 Hours
Gage in Feet

FIG. 1.

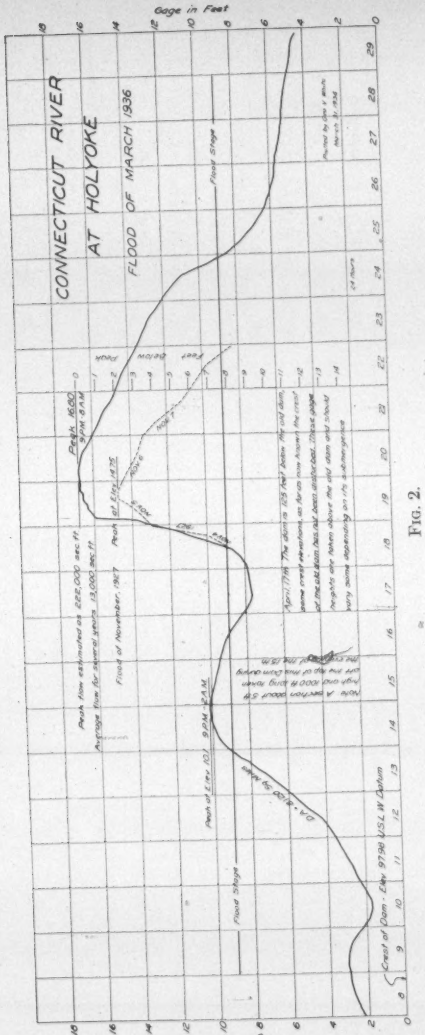
CONNECTICUT RIVER
AT HOLYOKE
FLOOD OF MARCH 1936
Gage in Feet
Flood Stage
Crest of Dam - Elev. 97.90 U.S.L.W. Datum

FIG. 2.

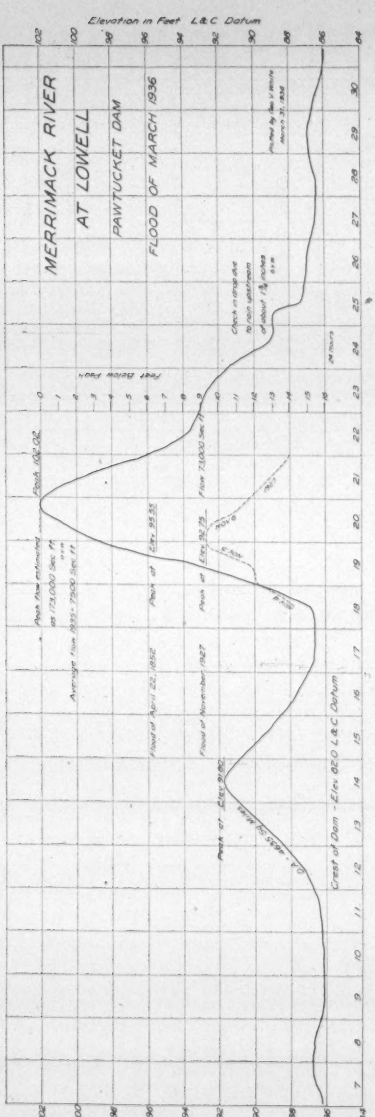
MERRIMACK RIVER
AT LOWELL
PAWTUCKET DAM
FLOOD OF MARCH 1936
Elevation in Feet L&C Datum
Feet Below Peak
Peak 102.02
Peak flow estimated as 173,000 Sec. Ft.
Average flow 1935 - 7500 Sec. Ft.
Flow 73,000 Sec. Ft.
Peak at Elev. 95.55
Flood of April 22, 1852
Peak at Elev. 92.75
Flood of November 1927
Peak at Elev. 91.80
Crest of Dam - Elev. 82.0 L&C Datum
Check in drop due to rain upstream of about 1¾ inches
24 hours
Plotted by Geo. V. White March 31, 1938

FIG. 3.

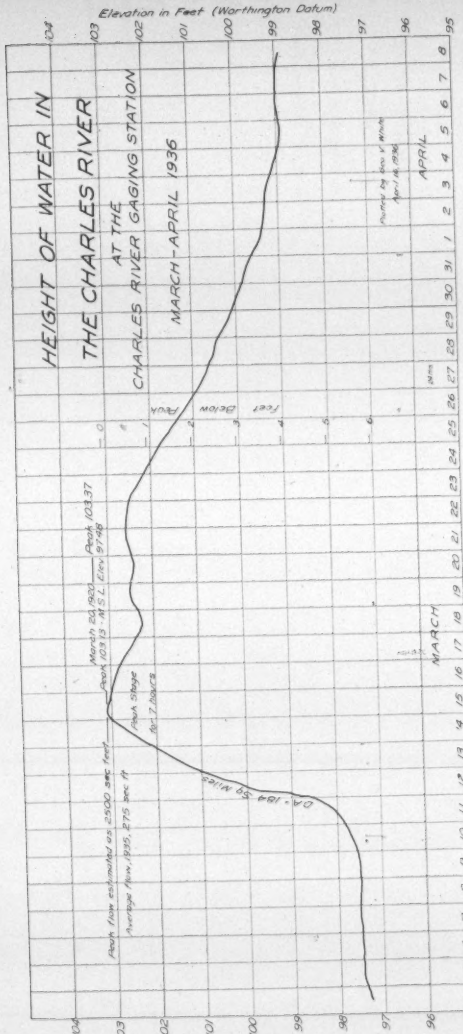
HEIGHT OF WATER IN
THE CHARLES RIVER
AT THE
CHARLES RIVER GAGING STATION
MARCH-APRIL 1936
Elevation in Feet (Worthington Datum)
Feet Below Peak
March 20, 1920 — Peak 103.37
Peak 103.13 - M.S.L. Elev. 97.48
Peak Stage for 7 hours
Peak flow estimated as 2500 sec feet
Average flow, 1935, 275 sec ft
DA = 184 Sq Miles
Plotted by Geo V White
April 16, 1936
MARCH
APRIL

FIG. 4.

streams. Tables 3 and 4 gives a comparison of the flow occurring during certain floods and under normal conditions.

TABLE 3.— FLOOD FLOWS IN THE CHARLES, HOUSATONIC, MERRIMACK AND CONNECTICUT RIVERS.

River.	FLOW IN CUBIC FEET PER SECOND.			
	1852. April.	1927. Nov.	1936. March.	Mean Annual.
Charles River at "Charles River" Gaging Station	.....	742	2 500	275
Housatonic River at Great Barrington.....	.....	5 690	8 500	525
Merrimack River at Pawtucket Dam, Lowell...	83 000	73 000	173 000	*7 500
Connecticut River at Holyoke Dam.....	.....	180 000	†222 000	‡13 540

* Average 1935. † Estimated. ‡ Mean at Sunderland and Montague.

TABLE 4.— INTENSITY OF FLOOD FLOWS.

River.	Drainage Area. Square Miles.	Flow in Cubic Feet Per Second. Flood of March 1936.	Flow in Cubic Feet Per Second Per Square Mile of Drainage Area.
Charles River.....	184	2 500	13.6
Housatonic River.....	280	8 500	30.4
Merrimack River.....	4 635	173 000	37.3
Connecticut River.....	8 120	222 000	27.4

Duration of Peak Flows. The duration of the peak flow is equally responsible with its intensity for the damage caused. It was the constant battering of structures by ice and débris that caused much of the damage and the continuous high flow that caused the serious erosion and deep silt deposits. Streams like the Charles that flood large areas of low land may have peak flows extending over a number of days, while in streams that are flashy like the Housatonic, the peak flow extends over but a few hours.

Table 5 shows the duration of the peak flows of March 1936 and the maximum flow of 1927 in the streams under consideration.

TABLE 5.— DURATION OF FLOOD FLOWS.

River. (1)	FLOW CUBIC FEET PER SECOND.		Number of Hours Flow March 1936 Was in Excess of Peak of Nov. 1927. (4)	Number of Cubic Feet Represented in Excess Flow as Per Column (3). (5)
	Peak Flow 1927. (2)	Peak Flow 1936. (3)		
*Charles River.....	742	2 500	396	1 758
Housatonic River.....	5 690	8 500	20	2 810
Merrimack River.....	73 000	173 000	96½	100 000
Connecticut River.....	180 000	222 000	69	42 000

* The November 1927 *Flood* on the Charles River watershed was small as the watershed lay outside the high-rainfall area.

Flood Damage. The excessive flows of the weeks of March 8 and 15, 1936, caused serious erosion of farm lands, especially in the Connecticut River Valley, and did considerable damage by leaving silt deposits on farm lands, inundating buildings and, in the case of the Merrimack, depositing silt on the filters used in connection with the water supplies of Lowell and Lawrence. The duration of the high flow caused dangerous delay in reconditioning the water supplies inundated and almost necessitated the pumping of unfiltered Merrimack River water into the distributing system of Lawrence to replenish the supply of that city.

The experience of the 1927 flood had taught the Engineering Division of the Massachusetts Department of Public Health that during such an emergency the washing out of highways, bridges and railroads may be expected to make travel difficult. Accordingly, the high water of the week of March 8 served as a warning and when still higher waters were observed during March 17 and 18, engineers were dispatched into the various river valleys with instructions to notify the home station of any unusual conditions and needs in the territory under supervision. Teletype communication with these men and with local boards of health was later provided through the State Police, a special officer being stationed for this purpose in the office of the Engineering Division. A radio was also set up but was of little value because of the large number of unconfirmable rumors being broadcast.

One very decided setback encountered in carrying out our work was the flooding out of the Lawrence Experiment Station. This necessitated abandonment of the station on the night of March 19 when the water had reached the top of the benches at which our chemists were working. These men loaded a boat at the work benches and took with them current bacteriological records and the tubes then in the incubators. A temporary laboratory was set up in a shed on adjoining property and incubation was maintained with the use of a gas range in the home of one of the chemists. In addition, it was necessary for us to distribute considerable bacteriological work to the Tri-town Laboratory at Lee and the Pittsfield City Laboratory in the valley of the Housatonic River, the laboratory of the Massachusetts State College and the laboratory of the Springfield Water Department in the Connecticut Valley and to the laboratories of the Harvard Graduate School of Engineering and the Massachusetts Institute of Technology and to one of our Boston consulting engineers who maintains a laboratory of considerable capacity in the city of Boston.

Because of our experiences during the week of March 8, when (1) the high water of the Housatonic River entered the ground water collecting works of the Great Barrington Fire and Water District, (2) the water of a tributary of the Ware River entered the dug well of the town of Ware, (3) the water of the Charles River washed out dikes and entered the wells of the town of Medway and of the Holliston Water Company and (4) the Quinebaug River submerged the well field at the Monson State Hospital,

we were better prepared for the extreme flood conditions of the following week. Chlorinating apparatus was already in use at Medway and Holliston, but it was necessary to make installations at Ware, Great Barrington and Monson. The high flows of March 19 and 20 saw all of these places again flooded out and so many other supplies in addition that a recommendation in the form of a radio broadcast was sent out for all consumers to boil the water. By rapid elimination, special teletype messages were later sent to all boards of health where we had knowledge that the water supply was not polluted, advising that boiling was unnecessary.

Table 6 lists the public water supplies that were seriously exposed to pollution during the floods of March 1936:

TABLE 6.— WATER SUPPLIES EXPOSED TO POLLUTION.

	Housatonic River.
Great Barrington Fire and Water District	Collecting gallery — a source of supply — inundated.
	Connecticut River.
Ware	Well inundated.
Athol	Mains washed out.
Orange	Mains washed out.
Winchendon	Well flooded.
	Merrimack River.
Fitchburg	Mains washed out. Burbank Hospital supply cut off.
Dunstable	Well field flooded.
Billerica	Well field flooded.
Methuen	Two well fields flooded, requiring taking water from Spicket River.
Lowell	Pumping Station, filters, well field and gravity conduit flooded.
Lawrence	Filters and Pumping Station flooded.
Newburyport	Artichoke River Pumping Station.
	Charles River.
Medway	Wells flooded.
Holliston	Collecting works flooded.
Dedham	Well field flooded.
Needham	Well field flooded.
Waltham	Wells threatened.
	Blackstone River.
Uxbridge	Well field flooded.
West Upton	Well field flooded.
Millbury	Well threatened.
Oxford	Well field flooded.
Grafton	Filter gallery threatened.
Leicester	Mains washed out, supply threatened.
Worcester	Mains washed out.
	Quinebaug River.
Monson	State Hospital well field flooded.

After receiving reports from our engineers concerning the various water supplies throughout the state it was obvious on March 20 that the most serious conditions were in the valley of the Merrimack River. Accordingly, most of our efforts were directed toward remedying the water supply situation in Lowell, Lawrence and Methuen in this valley.

Lowell. At Lowell, the water had flooded the well field and entered the Boulevard pumping station, filters and gravity conduit, but as soon as the river receded sufficiently fires were lighted under the boilers, the pumps were started and water was pumped direct from the wells into the gravity conduit.

At the head of the conduit, a makeshift apparatus was installed for chlorinating the water, and the water was wasted from the end of the conduit as it entered the 6th Street Pumping Station until a residual chlorine of at least 0.25 p.p.m. was maintained. Additional chlorinating apparatus was installed in the West 6th Street Pumping Station, and the water as it was pumped to the reservoir was treated again sufficiently to maintain a residual of about 0.4 p.p.m. This arrangement was continued until the reservoir was filled. The examination of samples of water collected from the West 6th Street Pumping Station, in the distributing reservoir and from taps in the city failed to show the presence of bacteria of the coli-aërogenes group.

Lawrence. At Lawrence, the river submerged the filters and lower part of the pumping station but, here, the engineers at the pumping station, realizing that they were to face extreme floods, removed the motors from the pumps and hoisted them to the floor above. Pumping stopped at 11.45 P.M. on March 19 when there were about 25 m.g. of water in storage. The water consumption just prior to the flood was about 5½ m.g.d., and as it would be a number of days before the filters could be operated, it was necessary to take water from Andover on March 21 and from North Andover on March 22. On this latter day a rumor spread over the city, as in Lowell, that the consumers might face a shortage and recommended the drawing and storing of water in utensils. This resulted in a draft on March 22 nearly equal to double the average and necessitated the water department sending out representatives to check all waste of water. Water was taken from Methuen on March 24, and the pumps were started at 10.50 P.M. on this date, pumping from the North covered and East covered filters, but it was obvious from the turbid condition of the water and the presence of small fish that improperly purified water was entering the pump well. Accordingly, chlorine was added in such quantities that a residual of over 1.0 p.p.m. was maintained in the water pumped and of over 0.2 p.p.m. in the water of the distributing reservoir when supplied to the city. The various filters were cleaned as rapidly as possible, but as they contained from 6 to 20 in. of silt, the work of cleaning was slow. Only the hand labor furnished by the WPA and CCC agencies was used. Connections were continued during this period with the water supply

systems of nearby towns, fire engines being used to maintain adequate pressure. The work of cleaning the filters was completed on April 6, and on April 7 the water in the reservoir was at an elevation equal to that before the flood. The bacterial examinations of samples of water collected from the distributing reservoir and from taps in the city failed to show the presence of bacteria of the coli-aërogenes group.

Methuen. The Methuen water supply is drawn from a gravel-packed well near the Spicket River at Harris Brook, three wells of similar type near the Merrimack River known as the "Lone Tree Hill" supply and a group of 2½ in. tubular wells near the Merrimack River at Pine Island. The wells at Lone Tree Hill on being flooded were abandoned, as the entire pumping stations in some cases were submerged. By protection from sand bag embankments, pumping at Pine Island was continued until that station also had to be abandoned and it was necessary to take water direct from the Spicket River at Harris Brook. Later, changes were made in the piping connections so that water could be pumped from both the well at Harris Brook and the Spicket River. Still later facilities were provided for again taking water from the wells at Pine Island. All water pumped was adequately chlorinated, and the bacterial examinations failed to show the presence of any organisms of the coli-aërogenes group in the water supplied.

Fitchburg. In connection with the Fitchburg supply, the flood waters of the Nashua River caused mains to be washed out and the Burbank Hospital to be without water. An engineer from our Department supervised the pumping of water from a nearby pond into the distributing system at this hospital and chlorination of the water until the public supply was again made available.

Another public health aspect to be considered in connection with floods is the subsequent low water in streams caused by the depletion of storage where dams have been washed out. In the case of one Massachusetts stream a very serious nuisance resulted where a municipality discharged untreated sewage into a stream. During periods of drought the sewage and industrial wastes from this municipality constitute a large percentage of the flow of the stream and with the washing out of a dam below the municipality, purification of the sewage by storage in the mill pond formerly at this site was not possible and a nuisance was created in a neighboring municipality.

Legislation. Since the spring of 1936 much has been done toward providing legislation to permit more adequate control of the flow of New England streams both for flood prevention and storage of water as a remedial measure against pollution. There was enacted by the Massachusetts Legislature during the 1936 session, Chapter 278 of the acts of that year, an act authorizing the State Planning Board to act jointly with commissions or individuals of other New England states or New York state to formulate compacts for the development of improvements to natural waterways common to any two or more of these states. There

has also been enacted by the Federal government Public Resolution No. 104 which authorizes the New England states, New York state and other states to enter into compacts "to conserve and regulate the flow and purify the waters of rivers and streams whose drainage basins lie within two or more of the said states." Meetings have been held between representatives of the Massachusetts State Planning Board and individuals designated by other states to enter into agreements or compacts, and an informal Compact Commission of New England has been organized, field examinations have been made of certain reservoir sites proposed by the United States Army Engineers for construction as flood detention reservoirs which have been considered also for use as equalising reservoirs, and construction work has actually been undertaken by the Army Engineers in some sections of the state for improving river channels to reduce damage by floods. The legislative body of the state of Connecticut passed legislation in the year 1935 to permit that state to enter into compacts in these matters, and in the early part of this year a compact commission was appointed by the Governor of Vermont, while under an act approved on June 28, 1935, the New Hampshire Water Resources Board was authorized to act in such matters. The great flood of March 1936 gave impetus to movements that had previously been started with a view of improving the New England streams. Under legislation to be provided we feel confident it will be practicable to construct at least some works that will not only materially lessen damage from floods in the future but will also reduce the danger to the public health from flood conditions.

At the time of writing of this paper it is interesting to note that while flood flows as great as 173 000 c.f.s. were experienced at the Pawtucket Dam in Lowell on March 20, 1936, flows recently have been recorded at this dam as low as 1 000 c.f.s. Measurements made of the flow in the Connecticut River at the dam at Holyoke recently have averaged for several days less than 3 000 c.f.s. while the flow over this dam during the flood of March 20 was as great as 222 000 c.f.s.

THE OHIO RIVER FLOOD OF 1936.*

BY F. H. WARING.†

[*Read September 23, 1936.*]

Frequency of Floods in the Ohio River. Flood stages in the Ohio River valley are not at all unusual. An ordinary flood stage may be defined as indicating a "bank-full" stream throughout practically its entire length. Such a flood stage occurs in the Ohio River on an average of once in every two years. Continuous records of river heights are available over many years at several Ohio River cities. One of the oldest river gages is that of the U. S. Weather Bureau at Cincinnati, where continuous records are available since June 1, 1858. The Cincinnati gage is representative of the river as a whole, because it is located nearly half way along the 967 miles from the source of the Ohio River at Pittsburgh to its mouth at Cairo, Illinois. A study of these records shows that *extreme* flood heights occur throughout most of the valley much less frequently. For example, the low-water level of the river at Cincinnati, as fixed by the navigation dams, is between 11 and 12 ft.; ordinary flood stages of over 50 ft. occur every two years; a flood causing considerable damage would be represented by a stage of over 60 ft., such stage occurring once in every eight years; an extreme flood in the Cincinnati district would be represented by a river stage in excess of 65 ft. and such stages occur on an average not oftener than once in every twenty-five years. The highest flood levels‡ attained at Cincinnati have occurred in 1884 (gage reading at 71 ft.) and in 1913 (gage reading at 69.8 ft.). The probable frequency of such extreme floods is once in 182 years for the 1884 mark; and for the 1913 mark, once in 126 years.||

It is apparent from the foregoing that floods in the Ohio River valley are common enough to force people to plan in some fashion against the liability of high-water stages. This fact alone accounts in large measure for the low property damage occasioned by great floods in this area. It is also apparent to the student of river records that a major storm over the entire watershed is necessary for extreme floods, at least extending half way down the nearly 1 000 miles of the river's length.

During the interval following March 17, 1936 the Ohio River was in extreme flood in its upper stretch of about 100 miles from Pittsburgh to below the Wheeling district; but by the time the crest reached the Marietta district, 170 miles from Pittsburgh, hardly more than ordinary flood height of the river was attained. Translated into previous high marks along the

* Discussion presented at the Annual Meeting of the New England Water Works Association at New York City, September 23, 1936.

† Chief Engineer, Ohio State Department of Health, Columbus, Ohio.

‡ Since this paper was presented, the Ohio River flood of January, 1937, reached a stage of 80 ft.

||From Allen Hazen in Proc. Am. Soc. C. E., Nov. 1913, p. 2113.

Ohio River, the 1936 flood registered the following: At the Pennsylvania-Ohio state line (East Liverpool, Ohio) over 3 ft. above the previous record; at Steubenville, Ohio, 67 miles below Pittsburgh, the river gage showed 3.4 ft. above the previous high-water mark of 1884; but at Marietta, Ohio, 170 miles below Pittsburgh, the river gage showed 11.9 ft. *lower* than the previous high-water mark set by the 1913 flood.

The relatively small portion of Ohio River watershed covered by the rains and melting snows of early March, 1936, namely the headwaters area, accounts for the relatively short stretch of Ohio River that experienced damaging effects.

Effects of 1936 Ohio River Flood. Aside from property damage, the 1936 flood affected the public located in Ohio municipalities to a relatively minor degree. From a public health standpoint, the damaging effects were confined to a few municipalities where complete service from public water supplies was interrupted for a short interval; to several small unincorporated municipalities not having public water supply facilities and where private wells and cisterns were inundated by the river water; and to isolated residential communities of the "cross-roads" variety similarly inundated.

There are seven cities and four villages located in Ohio along the 100-mile stretch of the river that experienced extreme high water. These municipalities are served by public water supply systems. Of these, three supply systems serving five municipalities were forced to interrupt supply service, the longest time out of service being four days (the old Bellaire filtration plant constructed in 1908). Generally speaking, the oldest supply works were hit the hardest, because in the newest works, such as the filtration plants serving East Liverpool, Toronto and Steubenville, the structures were built safely above all previous flood marks and, as recently demonstrated, enough higher to barely escape the river level of the 1936 flood.

The usual emergency public health measures were taken for these five municipalities temporarily without water service, such as hauling in water from an approved source, emergency supply with chlorination pumped from auxiliary sources, conserving of limited supplies in high-level storage reservoirs. Most of the effort in these places, however, was confined to clean-up operations as soon as the river level had receded the few feet necessary to permit resumption of regular operation. From the plant equipment standpoint, the damage was confined to wet motors that had to be baked out or replaced before service could be restored.

There were half a dozen rural communities in the flooded area that were inundated to the extent that private water supplies were polluted. With the aid of relief labor recruited under WPA these private water supplies were pumped out, cleaned of débris, and chlorinated; nearly 2 000 of these private supplies were treated. Flooded homes were likewise

cleaned of mud and disinfected as soon as possible. Red Cross assistance was also available in furnishing clothing, food and housing temporarily.

In all places where regular public water supply service was interrupted and in those few unincorporated municipalities not served with public water supplies, representatives of the state and local health departments administered anti-typhoid vaccine as a precautionary measure. The response to the appeal for this preventive treatment was excellent. It was estimated that over 15 000 people received one or more anti-typhoid treatments. No typhoid was experienced in the flooded area as a result. A dozen cases developed, however, in a small portion of one municipality located at some distance away from the river on high land; this municipality purchased water from the adjacent one that experienced a temporary shutdown of service due to the flood. The typhoid cases developed in three families that disregarded the advice to use only approved disinfected water supplies or boil all others, and drank from a neighbor's well that was alleged to be safe; the neighbors, however, revealed a rather recent history of having had typhoid. The State Department of Health administered the public health activity through five doctors, many nurses, three assistant sanitary engineers and three district sanitarians attached to county health units.

Discussion.

H. S. Hutton.* In times of disaster, — floods, hurricanes, cyclones, earthquakes — the most vital of public services are often affected and it becomes necessary to resort to temporary expedients until normal conditions can be restored. In the case of water service these disruptions may be due to any number of things — inability to secure water from normal sources, damage to distribution systems, power failures, flooded pumping stations, drowned out motors and so on — each calling for its own remedial measures.

When conditions are such as were experienced during the March floods all ordinary means of meeting such emergencies are often incapable of coping with the situation, and it is in such circumstances that extraordinary demands are made on certain manufacturers whose material or equipment is essential to the immediate restoration of service or the institution of emergency measures. Without in any way detracting from the heroic work of the communications and power-producing organizations, the pump and motor manufacturers and others, I would like to touch briefly on the emergency services of the chlorinator manufacturers and the makers of chlorine rendered at the time.

Bear in mind that in all an area 200 000 miles square — ranging from the Canadian border to the Carolinas and west through Ohio — was involved and that the New England States, in which we here are particularly interested, were only part of the whole picture.

* Of Wallace and Tiernan, Newark, N. J.

Because, in times of disaster, normal safeguards are often destroyed, new sources of pollution are opened up and questionable supplies are pressed into service, the first thought in either the restoration of normal service or the institution of emergency measures is the prevention of water-borne disease. Some means of effective disinfection — which today is almost synonymous with some form of chlorination — is the first need.

Realizing this, most chlorinator and chlorine manufacturers have issued standing orders that, in the event of any catastrophe involving water supplies, the field personnel in the affected area must report immediately to the supervising health authorities together with all available equipment and supplies. "Emergency Routine" devised from past experience goes into effect at head office, plant or factory. By following such procedure during the March floods it often meant that emergency equipment and materials were on the ground or on the way even in advance of the need which had been foreseen.

I recall that when about on March 17 the situation around Pittsburgh became serious. One truck load of emergency chlorinators together with trained personnel was started from Newark into the Pittsburgh area even though all reports indicated impassable roads. By driving night and day through snow and rain over hazardous and flood-swept roads, detouring miles from a normal route, this equipment and personnel were available for emergency installation work even before the other physical units could be assembled or pressed into service. Two days later an additional truck fought its way from Newark into the area with seven more emergency machines. In the meantime one chlorine manufacturer had dispatched from Philadelphia two truck loads each of nine tons of chlorine to the Pittsburgh area and two each of five tons to the Wilkes-Barre district, placing gratis sixteen tons of chloride of lime at the service of the Red Cross. Another chlorine manufacturer whose Pittsburgh stocks were six feet under water resorted to shipment by WPA, Red Cross and other commandeered motor transport to move stocks from Niagara Falls in all directions.

Emergency chlorinators were on two occasions flown from Newark Airport to New England health authorities. Major emergency chlorinator installations or rehabilitation of regular equipment were made at:

Endicott, N. Y.	Fitchburg, Mass.	North Andover, Mass.
Morrisville, Pa.	Lowell, Mass.	Sharpsburgh, Pa.
Binghamton, N. Y.	Mingo Junction, Ohio	Lawrence, Mass.
Waltham, Mass.	Pittsburgh, Pa.	

and several other places. Inspections were made throughout the entire flooded area.

Despite adverse weather conditions, hazardous travel, lack of sleep, shortage of food and water, no water supply in the affected area suffered or needed to suffer from the lack of adequate chlorinating equipment or chlorine. Ordinary business rivalries were forgotten. Often sales repre-

sentatives went to extremes to bring competitive materials and equipment through seemingly impassable areas, sat up nights operating or installing equipment of other manufacture, all without thought of recompense in any form, but not without sincere appreciation and readily extended thanks.

Speaking for the manufacturers I feel safe in saying that they consider these emergencies an opportunity to show their complete, whole-hearted coöperation with water works and public health officials and their equal responsibility for the protection of public health in time of such emergencies.

FACTORS TO BE CONSIDERED IN DETERMINING THE SIZE OF MAINS AND SERVICES.

BY SAMUEL H. MACKENZIE.*

[*Read September 25, 1936.*]

Next to an adequate supply of pure water, the pipe lines and services are the most important physical parts of a water system. During recent years, as plants have had cause to expand, inadequate supply mains, especially in smaller systems, have caused superintendents much thought and worry, and during these days of insufficient cash to permit necessary renewal of services they have also been a problem. Distribution mains that were too small to supply sufficient pressure at times of heavy summer draft have caused complaints. Much complaint has come also from property owners supplied through small galvanized service pipes installed 20 to 25 years ago on account of inability to draw from more than one faucet at a time. Twenty-five years ago, little thought was given in smaller systems to the chemical composition of the water being furnished or its action on the pipes.

In our town, practically all the original services installed about 1885 were of ¾-in. galvanized wrought iron pipe and answered the purpose very well in the "horse and buggy days" of single-faucet services. But with the addition of bath tubs, toilets, lavatories and sill cocks, the small pipes began to corrode quite rapidly and could not furnish a sufficient supply. Many of the services were replaced with 1-in. galvanized pipe 15 to 20 years ago, but with increased consumption those have proved little better than the ¾-in. services, so that we have found it necessary to give serious thought to the kind of service pipe to be installed.

Mains. Among the factors to be considered when installing a main pipe line are: (1) pressure available, (2) length of pipe line, (3) kind of pipe to be used, (4) probable regular draft, (5) probable draft during period of peek consumption, (6) character of property to be protected by hydrants, (7) physical and chemical qualities of the water supply, (8) character of soil, (9) location of line and (10) funds available.

All of these factors should be considered when determining the size of street mains together with (11) distance betwen cross-connections, (12) area to be served by hydrants, (13) belt-line connections and (14) possible extension of line either ahead or into side streets.

Every system should be mapped, and the map should include the adjacent territory that may later be served, so that when an extension is

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to be made, possible future extensions can also be considered. I think too many systems have been built just for the present, without regard for the future. My experience has been that renewals are much more costly than new installations. I have found it hard to convince some people that it is good policy to extend a 6- or 4-in. pipe with a larger pipe for the purpose of reducing friction loss and looking forward to the time when the smaller pipe will be renewed. We have found it valuable to have a map marked up with the proper size of pipe for renewals of the existing system and for new extensions. When an extension is under consideration, such a map will save much argument over size of pipe to be installed.

Every system should have a double supply if possible: if two mains cannot be included in the original installation, proper gates and tees should be installed for connections to the second line. If two lines are contemplated, the first line might be somewhat smaller than if only one is planned.

If sufficient funds were always available it would simplify planning, but where funds are lacking every effort should be made to install the main supply line and principal street mains of sufficient size to care for the requirements, saving on side streets if any cutting-down of expenditures must be done.

I believe a lined pipe should be used, unless the water in the system has practically no corrosive action on the pipe, as the lining reduces friction loss and the pipe will maintain practically its full carrying capacity for many years.

Services. In regard to size of pipe for services, the following general factors should be considered in determining the proper size: (1) Kind of pipe, (2) length of service, (3) water pressure, (4) character of water, (5) maximum draft, (6) cost of pipe, (7) kind of present and future pavement, and (8) character of soil.

If the water is corrosive and galvanized pipe is being used, our experience has been that the size should be not less than 1¼-in., but I would discourage the use of galvanized pipe in the highway and in service unless the water is of such a character that it does not corrode the pipe. If lead or brass pipe are being considered, ¾-in. pipe might be used in certain cases where the draft is small and liable to continue so, but, I favor 1-in. pipe, as the additional cost over ¾-in. pipe is small. As one superintendent has said "To install a service less than 1-in. in diameter is to invite trouble, should consumers install flushometers in the future" or for that matter any other fixture or develop a use that required a larger volume of water than a ¾-in. pipe would deliver.

On account of the large amount of permanent pavement that has been laid and is being laid it is very foolish to install a pipe that may prove too small or has no lasting qualities. If ¾-in. pipe is to be laid I favor ¾-in. red-brass pipe over the ¾-in. copper tubing as it has a larger inside diameter and when laid is straight so that in case a frog or lizard gets in,

it stands a better chance of coming through. Also a straight pipe can be thawed with hot water if it becomes frozen. Of course the sensible thing to do is to lay services below the frost line but changes in grade may occur which may bring the pipe into frozen ground.

I believe with the superintendent previously mentioned that for regular dwelling-house services 1-in. pipe should be the minimum size and that the kind of pipe used should depend on the character of water being drawn through it and the soil conditions. If copper tubing is used, great care should be exercised to lay it as straight as possible. I believe that 1¼-in. wrought-iron cement-lined pipe makes an excellent service and that it will have a long life if properly laid. I do not recommend it if it can not be laid straight from main to house.

Very careful consideration should be given to the various factors mentioned, as the installation of a water main is a work of too permanent a nature to be carelessly planned or carried out. It is not likely to be quickly replaced if it does not fulfill the purpose for which it was installed. The same might also be said in regard to service pipes.

RIGID VERSUS FLEXIBLE SERVICE CONNECTIONS.

BY ARTHUR C. KING.*

[*Read September 25, 1936.*]

The question of rigid versus flexible service connections is one upon which, I believe, most of us have quite decided opinions.

Flexible Connections. As flexible connections are more common I shall discuss them first. The advantage of a flexible service connection is of course that in case of settlement either of the main or of the service pipe no strain should come on the corporation, or the adjacent joints, great enough to break the corporation or cause a leak. There are several objections to this type of connection. The use of a gooseneck means that four joints of one kind or another are required close to the main, with just so many possibilities of leakage. With lead goosenecks, the joints between the lead and the bronze union couplings must be very carefully made by a trained man, whether they are swedged or wiped.

In some waters at least the lead of the gooseneck crystallizes or disintegrates after a period of years, losing its elasticity. Some of our worst leaks have been from the splitting of lead goosenecks that have deteriorated in this way. Another objection to goosenecks in a great many cases, is the galvanic action between the different metals brought together, i. e., the bronze corporation joined to the lead gooseneck followed by a bronze coupling to a pipe probably of still another material.

A gooseneck connection also hinders or prevents clearing a clogged corporation by use of a wire or rods without digging. We find a great many corporations partly plugged by tubercles in the main covering the inlet of the corporation if it does not protrude inside the main. If the tubercle is too hard to be removed by pumping a paper plug against it, the street must be opened so that the corporation can be "punched out."

Some of these objections to flexible connections can be overcome or avoided wholly or in part by various changes. Difficulties with the deterioration of lead can be avoided, of course, by using copper goosenecks, made up in the form of metallic hose or as tubing. This material, too, would probably reduce galvanic action somewhat, being more nearly of the same composition as the corporation. The cost of the metallic-hose gooseneck might be greater, and the thinness of the walls of the tubing adds the danger of reducing the waterway by flattening during installation, if the gooseneck form is followed.

Rigid Connections. Turning to rigid connections by which the pipe is coupled directly to the corporation, there is a decided reduction in the number of joints to be made, whether a union coupling is used or not, and

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these joints are of the same type as the rest of the pipe, so that no plumber or especially trained man is required to make them. By tapping the main on the side, a straight uniform waterway can be had from the main to the cellar, reducing friction loss from bends and increasing the ease of clearing any deposit in the pipe or corporation.

Whatever pipe material is used the elimination of a gooseneck of a material different from both that of the pipe and that of the corporation reduces the possibility of galvanic action. In connection with that feature, I might digress a moment from the title of this paper to mention that the so-called red-brass pipe rigidly connected to the usual corporation and sidewalk cock gives an entire service from main to cellar, of practically the same composition, *i. e.*, 85 per cent copper, with only a slight variation in the lead, tin and zinc of the other 15 per cent. This is the type of service we are using in Taunton, red-brass pipe, iron-pipe size, with full-size corporation and curb-cock. Copper tubing is not needed as we have almost no rock to dodge, and although red-brass pipe is a little more expensive in first cost, we believe it will be the cheapest in the end.

A rigid connection, to be sure, does not readily allow unequal settlement of the main and the service without putting strain on the corporation and possibly causing a leak. The remedy, however, is simply stated and quite practical in application, particularly when tapping old mains which usually have reached a permanent bed. This remedy, naturally, is to give both pipes solid support to prevent settlement.

It may seem that this is more easily said than done, but in Taunton for nine years we have been making rigid connections for all new services and many renewals, possibly about five hundred in all, with no difficulty. The only one out of five hundred that we have had to dig up, was not a broken or strained corporation but a stripping of the coupling between the pipe and the corporation. The exact cause for this we were unable to determine. It might be that part of the service pipe had been buried, before the connection was made at the corporation, and the last joint made up forcibly with a piece of pipe cut a trifle too short. The appearance of the coupling indicated such treatment.

To summarize: a rigid connection must be firmly supported, but reduces the number of joints to be made tight, obviates the necessity for a plumber or especially trained man to make up joints, cuts down galvanic action between metals by allowing the use of the same material throughout the service or reducing the number of kinds of material used, and makes possible a straight full-sized waterway the entire length of the service for greater carrying capacity and greater ease in cleaning.

AN INVESTIGATION OF THE KATADYN TREATMENT OF WATER WITH PARTICULAR REFERENCE TO SWIMMING POOLS.

BY ROBERT SHAPIRO* AND FRANK E. HALE.†

[*Read September 24, 1936.*]

For several years, experiments have taken place in Europe utilizing colloidal silver in minute dosage to sterilize water. One method has been to deposit the silver on solid material, such as porcelain or sand. A more recent method has been to pass the water between silver electrodes upon which a very low voltage current is imposed, and to alternate the current at intervals to prevent polarization of the silver electrodes. Owing to favorable reports of this process, extensive experiments were conducted at Mt. Prospect Laboratory during the years 1934–1935, for a period of about nine months, at the suggestion of the Health Department and the Park Department of New York City. This information was desired to ascertain whether the process could be utilized in place of chlorination for swimming pools, particularly the new ones planned or under construction by the Park Department.

The process under consideration is called the Katadyn Process and was represented in this country by Katadyn, Inc., Mr. Zeul in charge. Equipment for the tests was supplied by the company, both for laboratory experimentation and for practical treatment of a swimming pool. The work was carried out by Bacteriologist Shapiro under direction of the senior author of this paper. Conferences were held with various representatives of the company as well as Mr. Lawrence Addicks, engineer representing the silver interests, from whom extensive literature on the subject was obtained and studied.

The dosage of treatment is usually expressed in "gamma per liter." A gamma is 0.001 milligram. The literature indicated that effective dosage of water ranged from 50 to 200 gamma, or 0.05 to 0.20 p.p.m., to express it as in chlorination. The first experiments made in the laboratory utilizing cultures of *B. coli* indicated sterilizing effect after varying periods of time, though several wrinkles in the process appeared. In consequence, a practical test on a swimming pool was advised, and the Park Department took over control of a swimming pool at Bedford and Metropolitan Avenues, Brooklyn, at which the Katadyn Company installed a machine. The swimming pool water was recirculated, treated with alum and soda, filtered, and the Katadyn Process introduced between the filter and the pool. In

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addition to bacteriological tests, certain physical and chemical determinations were also made on the pool samples. The Katadyn Company also engaged a private laboratory to make check tests. Owing to discrepancies between the two sets of samples, occasional checks were made made at Mt. Prospect Laboratory, both in plating samples and in counting bacterial colonies. Exchanges of media were also made with the private laboratory. As the Katadyn Process is rather slow in action, all samples from the swimming pool were plated two hours after the taking of the samples to allow full action. The colloidal silver remains suspended for considerable periods of time and for this reason the company sought to maintain 150 gamma in the pool water, adding only sufficient silver continuously to maintain the desired quantity. All of these determinations reported on the swimming pool were made by the company as there is no simple method available for laboratory control. The determinations of silver concentrations were made by potentiometric titration with potassium iodide using a silver sulphide electrode and calomel electrode. The Katadyn machine was of such type that the entire recirculated water passed through it.

Action of Silver on B. coli. Seven strains of *B. coli*, 18-hour transplants, were used, one loopful of each mixed in one liter of tap water, Catskill supply, and permitted to stand for two hours for homogeneity before the silver was added.

	B. coli per c.c. 24-hr. Agar Count 37°C.
No. 1. Control	98
No. 2. Treatment for 23 min. to produce 200 gamma	6
No. 3. 10 minutes after treatment	0
No. 4. 20 minutes after treatment	0
No. 5. 30 minutes after treatment	0
No. 6. Treatment for 11 min. additional of No. 5 to produce 300 gamma	0
No. 7. 10 minutes after additional treatment	0
No. 8. 20 minutes after additional treatment	0
No. 9. 30 minutes after additional treatment	0

It is obvious from these results that during the time of producing 200 gamma, 23 minutes, considerable sterilizing effect on *B. coli* was accomplished and 100 per cent removal obtained in 10 minutes of further action. Naturally 300 gamma was excess treatment. However, the higher dosage produced a turbidity equivalent to about 1 p.p.m. on the silica standards used in water analysis.

The machine used in these laboratory tests was a hand set containing two silver electrodes with fixed distance apart to dip into the water to be treated. Voltage was obtained from two dry cells in parallel and current regulated by a rheostat. The capacity and rate of correction for the machine were furnished by the company. Dosage is estimated by multiplying amperage by time by the correction factor for the machine.

On account of the turbidity noted, Catskill water was treated with dosages of 100, 200, 300, and 400 gamma with resulting obvious and increasing turbidity, the highest dosage having a brownish appearance on standing. This question of turbidity is important in a swimming pool in which the water must be sparkling clear on account of its depth in order to prevent unobserved drowning.

Residual Action. In order to test the residual power of silver to sterilize, sample No. 9 which had been treated with 300 gamma, was reinoculated with *B. coli* with the following results:

	Total Count on Agar, 37°C., per c.c.	Brilliant-green Bile Test *B. coli* per 10 c.c.	
		In 24 hr.	In 48 hr
No. 10. After standing 24 hr., blank.....	0	0	0
No. 11. Immediately after reinoculation	220	10	100
No. 12. 10 minutes after reinoculation...	18	100	100
No. 13. 20 minutes after reinoculation...	1	10	10
No. 14. 30 minutes after reinoculation...	0	0	1

It is obvious that after 24 hours sufficient residual silver was in suspension to produce considerable sterilizing action on *B. coli* after 30 minutes.

Further to test the action of residual silver after a longer period of time, Catskill water was treated with 300 gamma, allowed to stand six days, and then inoculated with the previously mentioned seven strains of *B. coli*. The results are shown in the following table:

	Total Count on Agar per c.c., 37°C.		Brilliant-green Bile Test per 10 c.c.*	
	24 hr.	48 hr.	24 hr.	48 hr.
Immediate.....	560	1130	100	100
After 10 minutes.....	140	850	100	100
After 20 minutes.....	62	500	100	100
After 30 minutes.....	18	330	100	100
After 40 minutes.....	...	650	1	1

* Not tested beyond 0.1 c.c.

It is obvious that some but insufficient action remained after six days.

Dosage. The next test was arranged with a swimming pool water in which Catskill water was employed, and the effect of varying dosages of silver determined after 40 minutes' contact. The following results were obtained:

Dosage. Gamma.	Bacteria per c.c. Total Count Agar 37°C., 24 hr.		*B. coli* per 10 c.c. (After 40 Min. Contact.)	
	Control.	After 40 Min. Contact.	24 hr.	48 hr.
300	35	1	0	0
200	36	1	0	0
150	40	0	0	0
100	36	1	0	0
50	28	0	0	0
30	29	0	0	0
15	28	0	10	10

The bacteria in this test included residual bacteria in the pool water plus added pure cultures of *B. coli*. Residual chlorine was previously removed by one hour's aëration and was absent as shown by orthotolidin test. From these results the silver was effective with dosage of 30 gamma and 40 minutes' contact.

Salt Water. The next test was arranged to utilize a salt-water swimming pool at the St. George Hotel. This is supplied with a well water practically as saline as East River water. Residual chlorine was removed as before. The filtered water of the pool was utilized. One liter was treated with 300 gamma and dilutions made with untreated water. Pure cultures of *B. coli* were added as previously. The results are shown in the following table:

Dosage Gamma.	Bacteria per c.c. Total Count Agar 37°C., 24 hr.		*B. coli* per 10 c.c.* (After 40 Min. Contact.)	
	Control.	After 40 Min. Contact.	24 hr.	48 hr.
300	800	1560	100	100
200	650	1320	100	100
150	580	780	100	100
100	770	620	100	100
50	730	315	100	100
30	510	280	100	100
15	590	210	100	100

* Not tested in less than 0.1 c.c.

For some reason there was little or no action on the salt water in 40 minutes' contact even with 300 gamma. In consequence the test was repeated with the following results:

Dosage. Gamma.	Bacteria per c.c. Total Count Agar 37°C., 24 hr.		*B. coli* per 10 c.c.* (After 40 Min. Contact.)	
	Control.	After 40 Min. Contact.	24 hr.	48 hr.
300	31	33	100	100
200	40	31	100	100
150	27	30	100	100
100	36	30	100	100
50	34	29	100	100
30	35	17	100	100
15	32	23	10	10

* Not tested in less than 0.1 c.c.

It is obvious that again the silver treatment was without effect in the salt water.

Effect of Ammonia. In searching for the possible cause of failure of the Katadyn Process in the St. George Pool water, chemical analysis indicated the presence of free ammonia to the extent of 2.2 p.p.m. As ammonia forms a complex soluble salt with silver that might interfere with the sterilizing action, it was suspected that the presence of ammonia might be the cause of failure. This complex ion has the form $Ag(NH_3)_2$ and according to Treadwell and Hall, Vol. 1, p. 24, in a normal solution of

ammonia the ratio of concentration of this complex silver ammonia ion to the silver ion is about 10^7:1. To ascertain whether ammonia or its salts would interfere with the action of the silver, various concentrations in the form of ammonium chloride in Catskill water were treated with 150 gamma of silver because that is the amount generally maintained in a swimming pool. The cultures used for this test were isolated from agar plates of the Bedford Swimming Pool, 12 cultures in all, and included *Staphylococcus albus*, *Staphylococcus aureus*, and an unclassified *Streptococcus*. The results are expressed as percentages of the original amounts remaining after the intervals of time given and were as follows:

	Concentration of Ammonium Chloride — p.p.m. of Nitrogen.				
Contact Time.	0	0.25	0.8	1.1	1.4
None	100	100	100	100	100
10 minutes	72	81	94	92	96
30 minutes	64	65	77	85	91
60 minutes	51	52	60	72	82
24 hours	0.03	0.03	0.04	0.05	0.05

It is obvious that ammonia even in the form of a salt has a deterrent effect upon the action of the silver. Free ammonia undoubtedly has a greater effect. The effect increases with the amount of ammonia.

As the silver has been deposited upon sand, porcelain or other material and used in this form, it seemed desirable to ascertain whether the alum floc would accumulate silver in the filters used for recirculation of pool water. Both Catskill water and salt water from the St. George Hotel were used in a test. These waters were treated with 300 gamma of silver, clarified with filter alum, filtered and the filtrate tested after thirty minutes' action. The results were as follows:

	Catskill Water.			Salt Water.		
	Bact. per c.c.	*B. coli* per 10 c.c.		Bact. per c.c.	*B. coli* per 10 c.c.	
	24 hr.	24 hr.	48 hr.	24 hr.	24 hr.	48 hr.
Immediately after filtering	34	100	100	35	100	100
After 30 minutes.....	0	1	1	29	100	100

While the alum floc reduced turbidity caused by the silver, evidently sufficient was left in solution or suspension to cause sterilizing action in the Catskill water, but again there was no action in the salt water undoubtedly due to the effect of ammonia and not of filtration. The action of ammonia and ammonium salts is important since in swimming pools that are recirculated, accumulative increase of ammonia takes place due to contamination from swimmers.

TABLE 1.— BACTERIOLOGICAL QUALITY OF

Date. 1935.	Silver, Gamma per Liter.		Pool Outlet.			
			Before Filtration.		Filtered.	
	Added.	Total.	Bact. per c.c.	*B. coli* per 10 c.c.	Bact. per c.c.	*B. coli* per 10 c.c.
1—8	0	0	....	..	....	..
1—9	17	..	....	..	....	..
1—10	17	..	....	..	....	..
1—11	17	..	1 400	0	280	0
1—14	29	60	1 620	0	210	0
1—15	31	105	410	0	16	0
1—16	0	..	280	0	300	0
1—17	0	..	Not circulating.			
1—18	13	80	Not circulating.			
1—21	10	..	14 000	0	10 000	0
1—22	0	..	30 000	0	....	..
1—24	20	..	....	..	2 100	0
1—25	20	90	5 400	0	750	0
1—28	0	..	6 000	0	4 800	0
1—29	20	85	8 300	0	5 600	0
1—30	10	95	20 000	0	9 500	0
1—31	10	100	2 400	0	6 800	0
2—1	10	100	420	0	950	0
2—4	10	90	2 800	0	3 600	0
2—5	10	95	4 500	0	450	0
2—7	20	105	4 700	0	510	0
2—8	20	105	18 000	0	18 000	0
2—11	20	105	40 000	0	18 000	0
2—13	10	105	10 050	0	7 200	0
2—14	10	105	14 000	0	11 000	0
2—15	..	105	16 000	0	18 000	0
2—18	0	90	18 000	0	....	..
2—19	..	80	52 800	0	....	..
3—4	37	140	500 000	0	450 000	0
3—6	..	165	870 000	0	540 000	0
3—8	..	185	1 100 000	0	870 000	0
						Pool Emptied
3—18	35	50	75 000	0	65 000	1
3—20	..	65	....	..	....	..
3—22	..	80	350 000	0	270 000	1
3—25	..	80	150 000	0	70 000	0
3—27	..	70	500 000	0	400 000	0
4—5	..	70	700 000	1	550 000	0
4—16	..	110	85 000	0	45 000	0
4—28	..	120	350 000	0	110 000	0
6—4	..	90	550 000	10	450 000	10
6—7	..	80	160 000	10	150 000	0
6—12	..	60	55 500	0	45 000	0
6—18	..	120	13 900	10	12 500	10

Bacterial counts were obtained from agar plates incubated for 24 hr. at 37°C.

KATADYN-TREATED SWIMMING POOL WATER.

POOL OUTLET.		POOL.			
SILVER TREATED.		SHALLOW END.		DEEP END.	
Bact. per c.c.	*B. coli* per 10 c.c.	Bact. per c.c.	*B. coli* per 10 c.c.	Bact. per c.c.	*B. coli* per 10 c.c.
....	..	30 000	10	30 000	1
....	..	....	..	50 000	1
....	..	....	..	1 220	0
0	0	580	0	....	..
22	0	850	0	480	0
6	0	....	..	....	..
Not operating.		360	0	740	0
Not circulating.		8 200	0	7 700	0
Not circulating.		18 000	0	20 000	0
11 000	0	9 000	0	10 000	0
Not operating.		20 000	0	20 000	0
3 600	0	6 400	0	5 500	0
2	0	3 200	0	5 200	0
Not operating.		14 000	0	12 000	0
5 400	0	7 600	0	8 400	0
6 000	0	8 000	0	9 000	0
6 500	0	3 600	0	9 600	0
410	0	1 300	0	1 150	0
1 900	0	4 200	0	6 000	0
380	0	1 250	0	2 700	0
330	0	3 400	0	4 200	0
16 000	0	26 000	0	24 000	0
9 500	0	19 000	0	32 000	0
6 000	0	14 200	0	17 000	0
8 500	0	14 500	0	18 000	0
14 000	0	19 000	0	24 000	0
Not operating.		12 000	0	11 500	0
....	..	32 000	0	41 700	0
350 000	0	400 000	0	400 000	0
....	..	930 000	0	780 000	0
800 000	0	900 000	0	1 000 000	0
and Refilled.					
55 000	0	70 000	0	70 000	0
....	..	900 000	0	1 000 000	0
255 000	1	420 000	0	400 000	0
72 000	0	110 000	0	95 000	0
370 000	0	400 000	0	400 000	0
500 000	1	600 000	1	600 000	1
40 000	0	55 000	0	70 000	0
85 000	0	180 000	0	240 000	0
400 000	1	500 000	10	500 000	1
170 000	1	140 000	10	110 000	10
68 000	0	160 000	0	70 000	0
12 800	10	38 000	10	10 100	10

TABLE 2.— PHYSICAL, CHEMICAL AND BACTERIOLOGICAL

Date.	Source.	Bact. per c.c.	*B. coli* per 10 c.c.	Turb.	Color.	pH
1—8	Shallow	30 000	10	1	0	6.5
1—8	Deep	30 000	1	1	0	6.5
1—9	Middle	50 000	1	0	0	...
1—10	Middle	1 220	0	1	0	...
1—11	Outlet	1 400	0	2	5	...
1—14	Outlet	1 620	0	1	3	...
1—15	Outlet	410	0	2	0	...
1—16	Outlet	280	0	1	0	...
1—21	Outlet	14 000	0	0	7	...
1—22	Outlet	30 000	0	0	2	...
1—24	Outlet	5 500	0	0	0	5.7
1—25	Outlet	5 400	0	2	0	...
1—28	Outlet	6 000	0	..	..	...
1—29	Outlet	8 300	0	1	4	...
1—30	Outlet	20 000	0	1	6	...
1—31	Outlet	2 400	0	2	5	...
2—1	Outlet	420	0	1	2	...
2—4	Outlet	2 800	0	1	5	5.9
2—5	Outlet	4 500	0	1	2	...
2—7	Outlet	4 700	0	1	0	...
2—8	Outlet	18 000	0	1	0	...
2—11	Outlet	40 000	0	2	0	...
2—13	Outlet	10 000	0	1	0	...
2—14	Outlet	14 000	0	2	0	5.9
2—15	Outlet	16 000	0	1	0	...
2—18	Outlet	18 000	0	2	0	...
2—19	Outlet	52 800	0	2	0	...
3—4	Outlet	500 000	0	2	6	...
3—6	Outlet	870 000	0	2	4	...
3—8	Outlet	1 100 000	0	7	8	...
3—18*	Outlet	75 000	0	2	7	...
3—20	Shallow	900 000	0	2	7	6.8
3—22	Outlet	350 000	0	2	3	...
3—25	Outlet	150 000	0	2	3	6.9
3—27	Outlet	500 000	0	1	5	6.8
4—5	Outlet	700 000	1	1	0	6.8
4—16	Outlet	85 000	0	0	5	6.9
4—28	Outlet	350 000	0	7	2	6.9
6—4	Outlet	550 000	10	2	2	7.0
6—7	Outlet	160 000	10	1	2	7.0
6—12	Outlet	55 000	0	4	4	7.2
6—18	Outlet	13 900	10	2	2	7.0

* Pool refilled.

With exception of bacterial and *B. coli* counts, pH and silver, results are expressed 24 hr. at 37°C.

QUALITY OF KATADYN-TREATED SWIMMING POOL WATER.

Ammonia Nitrogen.	Albuminoid Nitrogen.	Nitrite Nitrogen.	Nitrate Nitrogen.	Chlorides.	Alkalinity.	Silver, Gamma per Liter.
.560	.216	.003	.15	2.0	7	None
.672	.200	.002	.10	2.0	7	None
.640	.280	.002	.10	2.0	6	None
.632	.200	.002	.10	1.8	6	Started
.816	.216	.012	.15	2.0	5	...
1.680	.144	.006	.10	1.7	3	60
1.440	.320	.004	.15	1.6	3	105
1.240	.640	.003	.30	0.8	3	...
2.900	1.800	.002	.10	0.4	3	80
2.400	.520	.007	.40	0.4	1	...
2.000	1.200	.005	.20	1.1	1	...
1.640	.640	.005	.20	2.0	1	90
2.100	.840	.004	.30	1.2	6	...
1.440	.640	.012	.40	0.6	3	85
1.720	.640	.003	.20	0.4	3	95
1.560	.320	.008	.20	0.4	1	100
1.160	.800	.008	.50	1.0	2	...
1.760	.600	.008	.40	0.4	2	90
.560	.840	.006	.55	0.6	2	95
2.000	.800	.008	.45	2.0	2	105
2.760	1.200	.006	.55	2.4	3	105
1.720	.960	.014	.40	1.2	3	105
2.220	1.880	.011	.25	1.2	1	105
2.840	1.080	.010	.60	2.2	1	105
1.920	1.600	.007	.65	2.8	2	105
1.200	1.360	.012	.70	1.2	6	90
3.000	1.160	.006	.65	2.6	5	80
4.600	1.160	.096	1.45	5.2	25	140
4.000	1.040	.160	1.40	5.2	30	165
4.400	.800	...	...	6.0	34	180
1.040	.760	.028	1.45	6.4	15	35
1.440	1.200	.002	1.85	8.0	21	65
1.040	1.040	.040	1.80	7.6	19	80
1.560	1.000	.013	1.60	7.6	22	80
2.120	1.000	.012	1.95	7.2	30	70
1.840	1.760	.006	2.10	6.8	23	70
.920	.720	.003	.05	5.2	13	110
1.240	1.560	.006	1.40	8.8	21	120
12.400	3.600	.048	.85	15.0	35	90
8.400	3.600	.032	1.35	17.6	40	80
6.000	11.200	.250	1.35	18.8	47	60
9.000	3.000	.640	.95	20.8	5	120

in parts per million. Bacterial counts were obtained from agar plates incubated for

A further test with ammonium chloride in higher dosage and longer intermediate time was made using Catskill water and the same organisms as previously. Results are again expressed as per cent. residual.

	Concentration of Ammonium Chloride — p.p.m. Nitrogen.				
Contact Time.	2.0	2.5	3.0	4.1	5.0
None	100	100	100	100	100
2 hours	46	48	44	66	67
5 hours	23	30	34	41	41
24 hours	1.5	4.5	4.5	6.9	7.6

These results agree with the previous results obtained with an ammonium salt showing delayed action increasing with amount of ammonia present.

Effect on Staphylococcus aureus. The slow disinfecting action of the silver is also demonstrated in the following table carried out with a standard culture of *Staphylococcus aureus* in the manner of determining the phenol coefficient:

Catskill water was treated with 200 gamma of silver and inoculated with a pure culture of the organism using an 18-hour transplant.

Immediate	15,000 per c.c.
1 hour	0 per cent reduction
2 hours	10 per cent reduction
3 hours	20 per cent reduction

The action was too slow to be expressed as a phenol coefficient.

Swimming Pool Tests. The tests upon the swimming pool comprised 183 samples from January through June, 1935. Tables 1 and 2. Bacterial samples were taken at five points: prior to filtration, after filtration, after silver treatment, and surface samples from the pool at the shallow end and at the deep end. The results of these tests are shown in Table 1. In addition, turbidity, color, odor, alkalinity, pH, chloride, nitrite, nitrate, free ammonia, and albuminoid ammonia were determined on samples taken before filtration representing the effluent water of the pool. These results are shown in Table 2. There was no chlorination of the pool water. The supply was Catskill water, Long Island water or a mixture of the two.

The sample taken after filtration was collected with two points in view: to ascertain the effect of filtration and any possible effect of silver accumulated on the filter, and for comparison with the samples taken after treatment with the silver. It is obvious from the figures for bacteria that the silver treatment was practically without effect either through accumulation on the filters or after direct application. The dosage was entirely controlled by the Katadyn Company, and the figures given for the treatment were determined by them. Several times the machine was out of order and was repaired. Short circuiting of plates was caused by sand from the filter. The bacterial figures are 37° C. counts, and from the plates

were isolated *Staphylococcus albus*, *Staphylococcus aureus* and a *Streptococcus*. Bacteria of this type may be of importance in eye, ear, nose and throat infections which are thought to be transmitted at times in swimming pools. In addition, numerous chromogenic forms, sporulating bacteria, and gram-positive diplococci were isolated.

A glance at the chemical figures indicates accumulation of considerable free ammonia in the pool water, even to the extent of 12 p.p.m. in one instance and its general presence in 1 to 3 p.p.m. It is quite probable that this accumulation of ammonia from the swimmers may explain the failure of the silver to sterilize, particularly since the first three results apparently showed effect. *B. coli* was generally absent even in the pool water, with exception of the later tests.

Comparative Counts. It has been mentioned that the bacterial counts at the private laboratory employed by the Katadyn people were lower than those obtained at Mt. Prospect Laboratory. Considerable study was made of this question. The private laboratory was making counts at first on Endo's medium and at our suggestion changed to standard agar. In all probability they omitted to count pin-point colonies that frequently occur in swimming pool analyses. Our laboratory experience with swimming pools has been gained from weekly analyses of pools under control of the Board of Education, Board of Health, Borough President Manhattan, Department of Parks, Long Island State Fark Commission, etc. The same media were used at Mt. Prospect Laboratory as in all our work. The following table shows one of the check counts made at Mt. Prospect by two men on media of the two laboratories using pool water:

	Mt. Prospect Laboratory Agar.	
Location.	Shapiro.	Askowitz.
Outlet of pool	52 800	56 400
Shallow end of pool*	32 700	32 400
Deep end of pool†	41 000	50 400
Tap water at pool	12	12
	Private Laboratory Agar.	
Location.	Shapiro.	Askowitz.
Shallow end of pool*	2 410	2 340
Deep end of pool†	1 350	1 740

*† Same samples.

Silver has an action upon algæ similar to that of copper. Before starting the experiments, the empty pool was carefully examined to observe whether any discoloration should be caused by either algæ or by deposit of silver. Toward the end of the experiment some green growths were noted on the pool wall including fungi, rotifera, protococcus and conferva. The lowest tiles had a grayish discoloration difficult to remove that may have been caused by the silver, but no test was made to confirm this possibility.

Conclusions. It is felt that in the present stage of development the Katadyn Process cannot be approved for use in swimming pools for the following reasons:

While laboratory results indicate that the *B. coli* group may be controlled in the absence of ammonia, both laboratory experiments and swimming pool results indicate that the 37° C. count of bacteria is not affected, and among these bacteria may be disease germs affecting the eye, ear, nose or throat.

Even when the silver treatment has been considered effective, the literature indicates that two hours time is required for effective results, and this delay does not seem desirable. Not only must the pool water be sterilized, but the swimmer should be protected by quick action against contamination by other swimmers.

The treatment must evidently be studied in connection with the particular water in which it is to be used. Apparently it does not work well with Catskill water, nor with such salt water as that used in the St. George Hotel Pool, nor with Long Island water.

Ammonia present in the water prevents obtaining good results and in addition to the possible presence of ammonia in the source of supply it also tends to accumulate to a serious extent from contamination by swimmers. Not only has this been shown to be the case in the Bedford Pool but analyses of other pools made several years ago have shown the same accumulation.

Quicker results might be attained with higher dosage but apart from cost there is the decided possibility of turbidity in the pool which might permit drowning without observation in the deeper portions of the pool. For this reason it is very essential that pool water be sparklingly clear. With Catskill water in the laboratory this turbidity was very noticeable.

At the present time there is no adequate simple method for determination of silver in the pool water. With chlorination control tests are readily made by the pool operator.

There is a most decided question as to economy of the treatment when compared with chlorine. The recommended dosage of silver is one that will maintain in the pool 150 to 200 gamma, *i.e.*, 0.15 to 0.20 p.p.m. Even making allowance for lesser dosage in the daily increment, when it is recalled that silver costs several dollars per pound against a few cents per pound for chlorine, the cost is hardly comparable.

Another possibility is the production of a disease called argyrosis in which the skin is permanently darkened by deposit of silver. Once developed, there is no cure, a serious situation. In the *Journal of the American Medical Association*, Vol. 104 (April 20, 1935) pp. 1387–90, is given an account of 70 cases of generalized argyrosis following organic and colloidal silver medication, among which was the use of argyrol. It was indicated that as little as 8 grams total treatment with silver arsphenamine has caused the disease, and caution was given against the continued use of silver remedies. If silver treatment of swimming water or drinking water became prevalent it seems quite within the realms of possibility that skin discoloration might be produced.

PROCEEDINGS.

NOVEMBER MEETING.

HOTEL STATLER, BOSTON, MASS.

Thursday, November 19, 1936.

President Harry U. Fuller in the Chair.

Secretary Gifford announced the following elections.:

Members: Ernest A. Merrithew, Superintendent, Saugus, Mass.; Eugene M. Repucci, Water Engineer, Medford, Mass.; Fred B. Nelson, Assistant Engineer, Department of Water Supply, Gas & Electricity, New York, N. Y.; Everett M. Battey, Assistant Chemist, Purification Works, Providence, R. I.; Ernest E. Tankard, Assistant Superintendent and Cashier Berlin Water Works, Berlin, N. H.; George J. Cote, Commissioner, Haverhill, Mass.; Morton R. Milne, Commissioner, Haverhill, Mass.; Henry C. Jones, Associated Factory Mutual Fire Insurance Companies, Boston, Mass.; John D. Mackay, Cos Cob, Conn.; Harold L. Carter, Boston Manufacturers Mutual Fire Insurance Company, Boston, Mass.; John B. Moore, Commissioner, Milton, Mass.; Michael J. Hannigan, Foreman Inspector, Water Department, Milton, Mass.; Wayne F. Damon, Filter Operator, Leominster, Mass.; Maurice Burwick, Filter Operator, Leominster, Mass.; Lyndall K. Parker, Assistant Superintendent, Auburn Water District, Auburn, Maine.; William J. Perry, 2nd, Superintendent, Cotuit, Mass.; Edward W. Moore, Instructor, Harvard Graduate School of Engineering, Belmont, Mass.

Corporate Member: Milford Water Company, Milford, Mass.

Under the Chairmanship of Stephen H. Taylor, the meeting was devoted to a discussion of matters related to a report of the Committee to Consider the Advisability of Water Works Regulation of Inside Plumbing and Fixtures.

A paper on "Special Equipment Cross-Connections" was read by Arthur V. Harrington, Assistant Engineer, Massachusetts Department of Public Health.

A paper, "Cross-Connections in Plumbing Fixtures" was read by Mr. E. L. Penfrase, Copper and Brass Research Association, New York, N. Y. Mr. Penfrase also showed a visual educational film illustrating syphonic action through cross-connections or faulty plumbing.

A paper, "What Interest Has a Water Purveyor in Interior Plumbing Systems in Relation to Cross-Connections," was read by M. Warren Cowles, Health Officer, Hackensack Water Company, New Milford, N. J.

A paper, "Attitude of Master Plumbers" was read by John J. Downey, President, Massachusetts State Association of Master Plumbers.

A paper, "Safety Devices for Water Heating Apparatus," was read by Ernest G. Parker, Inspector of Plumbing, Health Department, New Bedford, Mass.

A paper, "Plumbing Fixtures Subject to Back-Siphonage," was read by Leslie K. Sherman, Assistant Engineer, State Department of Health, Hartford, Conn.

A paper, "Electric Grounding on Water Pipes," was read by J. O. R. Coleman, Edison Electric Institute, New York, N. Y.

A paper, "Tanks for Water Service in High Buildings," prepared by Henry E. Halpin, Engineer, Associated Factory Mutual Fire Insurance Companies, Boston, was read by Richard H. Ellis.

A paper, "Size, Type, Location and Materials used for Service," was read by Stephen H. Taylor, Superintendent, Water Works, New Bedford, Mass.

December Meeting

Hotel Statler, Boston, Mass.

Thursday, December 17, 1936.

President Harry U. Fuller in the Chair.

Secretary Gifford announced the election of the following new members:

John M. Magee, Superintendent, Water Department, North Reading, Mass.; Ralph A. Marble, Technical Supervisor, Nashua Valley Survey, Fitchburg, Mass.

Mr. Walter L. Hess of the Community Federation of Boston gave a short talk regarding the coming campaign.

Mr. John R. Campbell, Jr., Regional Representative of the Federal Old Age Bureau, spoke on "Social Security as It Applies to You." Patrick Gear, Henry T. Gidley, Donald C. Calderwood, William F. Sullivan, David E. Moulton, and Percy A. Shaw took part in the discussion.

A paper, "The Water Purification Plant at Northborough, Massachusetts," illustrated with stereopticon views, was read by Robert Spurr Weston, of Weston and Sampson, Consulting Engineers, Boston, Mass.

A discussion of the papers presented at the meeting of November 19, on the Advisability of Water Works Regulation of Inside Piping and Fixtures, was led by Stephen H. Taylor, Superintendent, Water Works, New Bedford, and participated in by Donald C. Calderwood, M. Warren Cowles (Health Officer, Hackensack Water Company, New Milford, N. J.), John J. Downey (President, Massachusetts State Association of Master Plumbers), Patrick Gear, David A. Heffernan, and Warren J. Scott.

JANUARY MEETING

HOTEL STATLER, BOSTON, MASS.

Thursday, January 21, 1937.

President Harry U. Fuller in the Chair.

Secretary Gifford announced the election to membership of Carl A. Clark, Marlboro, Mass.

A paper, "Painting Problems in General," illustrated, was read by James A. Meacham, Sherwin-Williams Co., Cleveland, Ohio.

A paper, "Aluminum Paint as an Engineering Material," illustrated, written by Robert I. Wray, Aluminum Research Laboratories of the Aluminum Company of America, New Kensington, Pa., was read, in the absence of Mr. Wray, by Junius D. Edwards of the same company.

A paper, "Protection Problems Peculiar to Water Works," illustrated, written by George E. Boyd, Wailes Dove-Hermiston Corporation, Westfield, N. J., was read, in the absence of Mr. Boyd, by W. D. Barker, New England representative of the same company.

A paper, "Painting of Concrete in Water Works, for Decorative, Protective and Waterproofing Purposes," was read by Dr. A. F. Pistor, Inertol Co., Newark, N. J.

These papers were discussed by Bayard F. Snow, Alfred O. Doane and Allen M. Symonds.

FEBRUARY MEETING

HOTEL STATLER, BOSTON, MASS.

Thursday, February 18, 1937.

President Harry U. Fuller in the Chair.

Secretary Gifford announced the following elections:

Members: Joseph E. Tracy, Pitometer Company, Albany, N. Y.; Charles R. Cox, New York Department of Health, Albany, N. Y.; John W. Hughes, Foreman Water Department, Attleboro, Mass.

Associate: J. H. Tredennick, Inc., Painting, Boston. Mass.

A paper, "Operating Experiences at the Salem and Beverly Filtration Plant," illustrated, was read by Robert P. Johnson, Chemist, Salem and Beverly Water Supply Board, Beverly, Mass.

A paper, "Experiences with Chlorinating New Water Mains and Other New Works," illustrated, written by Francis H. Kingsbury, Senior Sanitary Engineer, and George O. Adams, Chief of Laboratory, Massachusetts State Department of Health, was read by Mr. Kingsbury.

A paper, "Chlorination of a Cambridge Main," was read by Fred E. Smith, Chemist, Cambridge Water Filtration Plant, Cambridge, Mass.

A paper, "Water Chlorination Experience," was read by Frederick O. A. Almquist, Senior Sanitary Engineer, Connecticut State Department of Health.

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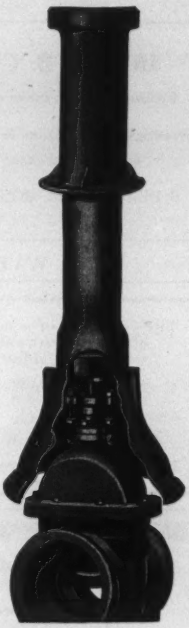

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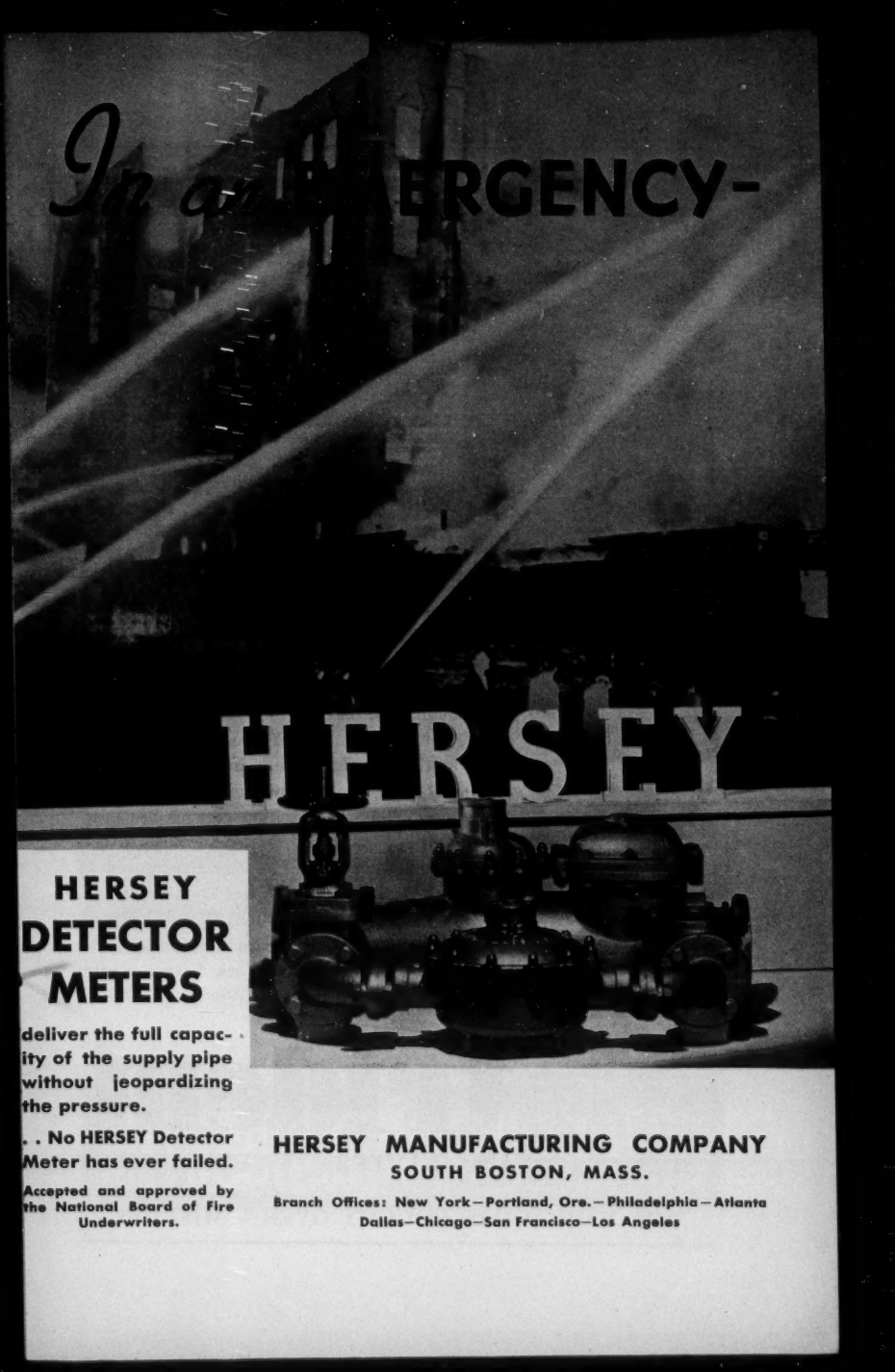

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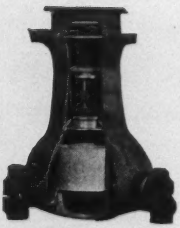

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Although the Idaho potato has gained national fame, the story of the opening and development of the Twin Falls tract appears almost like a myth to those unfamiliar with the actual latent possibilities of the fertile farm lands. In the short space of some thirty years a barren sagebrush desert has been conquered agriculturally and cities and towns, modern in every aspect, have been built.

The City of Twin Falls, Idaho, serves a trading area of 600,000 acres. The fact that more than 10,000 carloads of agricultural products are shipped from this district annually is proof of the productiveness of this fertile rich farm land.

A tribute to Pittsburgh Water Meters and the success of their 100% metered water supply is expressed by this statement from Mayor Johnston, "I have checked the use of meters with our various departments, such as Finance, Distribution, Filtration and Sewage, and the various heads of these departments all concur that it would be next to impossible to operate our Water System without the use of water meters."

PITTSBURGH EQUITABLE METER CO.
MERCO NORDSTROM VALVE CO.
MAIN OFFICES PITTSBURGH, PA.

NEW YORK LOS ANGELES TULSA HOUSTON MEMPHIS BUFFALO
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PITTSBURGH WATER METERS

THE STANDARD FOR OVER 50 YEARS

Automatic Pressure Control Valves
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Altitude — Pressure Reducing — Surge Relief and Combination Valves
Portable Fire Hydrants
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ROSS VALVE MFG. CO., INC. TROY, N.Y.

Health and Protection First

Water delivered through dirty pipes may be a MENACE.

Incrusted water pipes mean inefficiency and loss of Fire Protection.

We Guarantee the Results of Our Method of Cleaning.

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National Water Main Cleaning Co.

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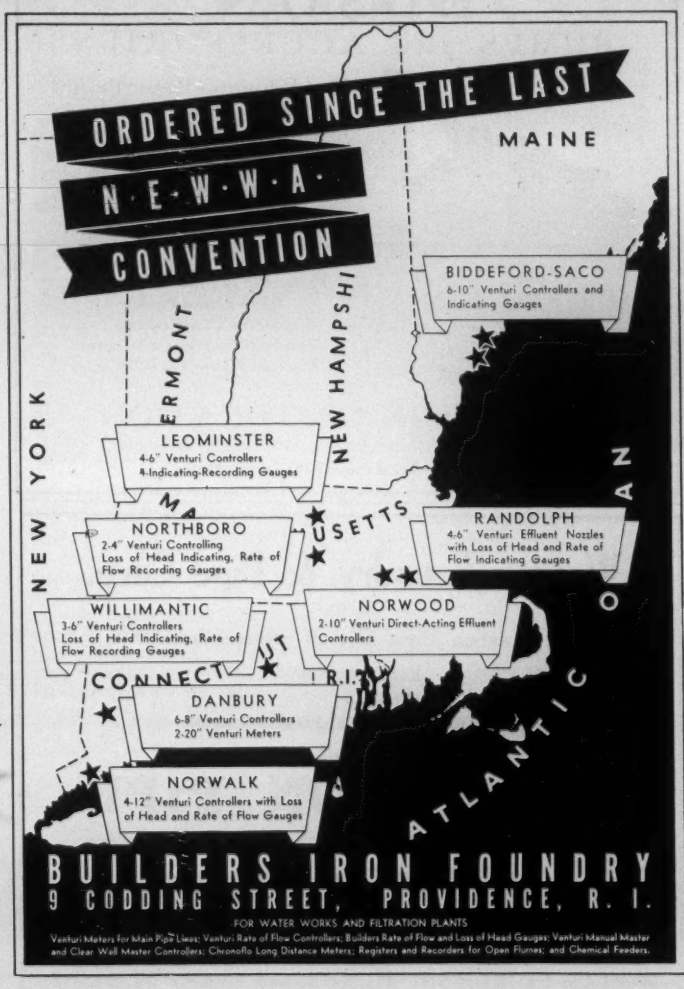
Water-works Practice and Theory

WHEN you wish information on any phase of water-works practice, let us look up the subject for you in our Journal.

In one of the issues there will be the material you want.

Back numbers of the Journal are available at **$1.25** per copy.

New England Water Works Association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EDSON
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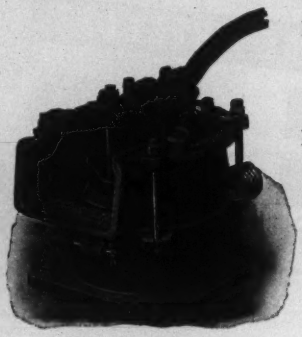

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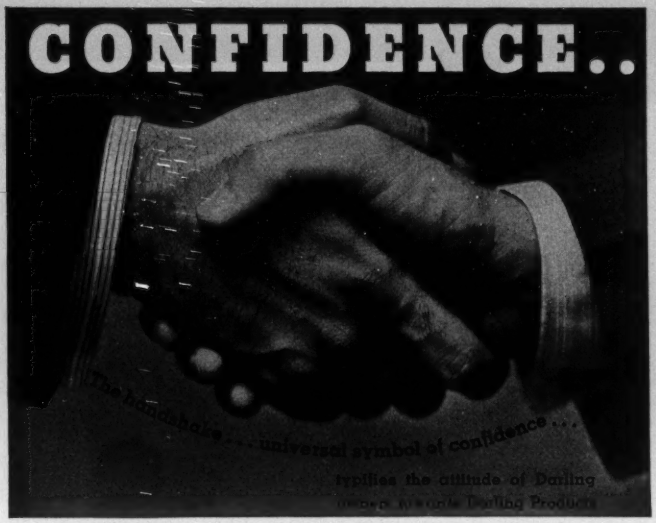

Confidence in Darling Products is characteristic. We who make them believe that Darling Gate Valves and Fire Hydrants are just about as fine as could be desired. Our customers are steady customers—which indicates that ***they*** share our opinion.

Darling Valves and Hydrants justify this confidence. They afford trouble-free service over long periods of time. Performance of this kind pays dividends in ***reduced maintenance cost.*** Have you particular problems in regard to valves or hydrants? The nearest Darling representative will be glad to talk them over with you—no obligation, of course.

The large barrel of the Darling Hydrant insures a plentiful supply of water—and there are many other advantages.

DARLING VALVE & MFG. COMPANY

Williamsport, Pa.

Representatives in:

New York	Oklahoma City
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Darling Valves are the choice of those who insist on performance.

DARLING

GATE VALVES and FIRE HYDRANTS

"Never a Failure in Over 22 Years!"

WE like to talk about saving in material and labor—the strong, tight, flexible joints made with Hydro-Tite—the thousands of miles of pipe jointed with it.

More important, perhaps, is the fact that with hundreds of users—each laying pipe under different conditions—not a single one has reported a Hydro-Tite failure.

We make it very easy for you to change over to Hydro-Tite. Our Data Book outlines a novel proposition. Write for it.

HYDRO-TITE

A Symbol of Quality

A Dependable Self-Caulking Joint Compound

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At the PENNICHUCK WATER WORKS

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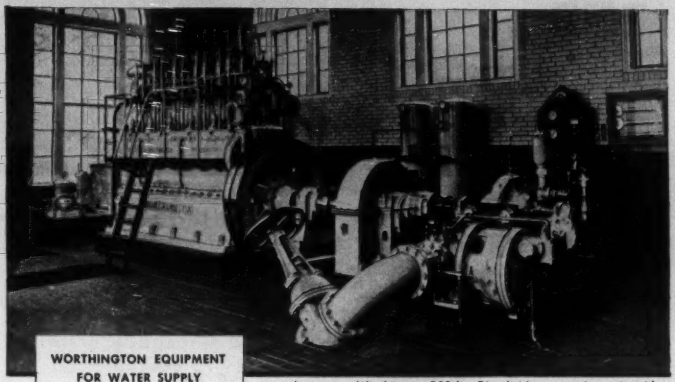

A compact Worthington 250-hp. Diesel-driven pumping unit, with a capacity of 6,000,000 gallons per day. It costs only a third as much to operate as the huge steam plant formerly used.

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CENTRIFUGAL PUMPS
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AIR LIFT SYSTEMS
*WATER METERS

THIS modern Worthington water works installation is but one of the hundreds which are successfully serving forward-looking communities throughout the country.

Worthington equipment for water supply comprises a most comprehensive line...not only main units of every type and size but all auxiliary equipment...**a complete service with undivided responsibility.**

● *Complete descriptive literature available*

*A complete line of water meters of every type is manufactured by Worthington-Gamon Meter Company, a subsidiary of Worthington Pump and Machinery Corporation.

WORTHINGTON PUMP AND MACHINERY CORPORATION

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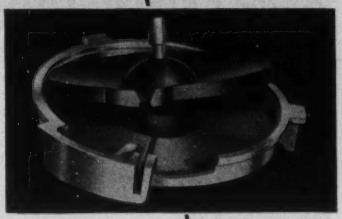
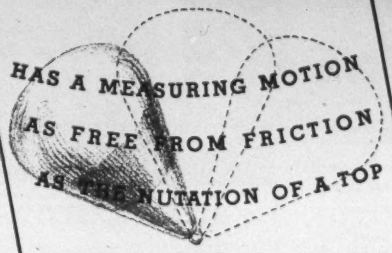
L. H. NASH

A NATIONAL NAME FOR ACCURATE DEPENDABLE ECONOMICAL WATER METERING

THE V-type DISC





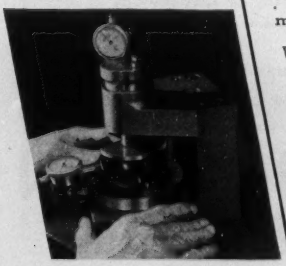
Friction and wear . . . the common causes of increasing inaccuracy and repeated replacements of water meters . . . are reduced to a minimum in the L. H. Nash Meter by exclusive design features.

The V-Type Disc, for example, does not demand such mechanical control devices as thrust rollers or control blocks. The disc lays on its side and nutates around its precision-finished, water-lubricated, hard-rubber ball, balanced by the pressure at inlet and outlet ports.

Thus the measuring motion of this meter is a pure rolling motion . . . as free from friction as the nutation of a top. Less friction assures less trouble . . . provides more years of accurate metering at less cost.

Other features of the L. H. Nash Water Meter are advantageous, too . . . why not write for complete information . . . today?

The L. H. Nash Meter is also manufactured to minimize friction. The V-Type Disc alone must pass seven exacting inspections . . . including measurements made in one-ten-thousandths of an inch! Thus design and construction are co-ordinated to produce a water meter that is accurate, dependable, and thoroughly economical.



NATIONAL METER COMPANY

4209 FIRST AVENUE, BROOKLYN, N. Y.

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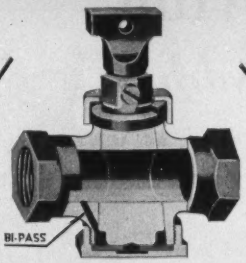
CALDWELL

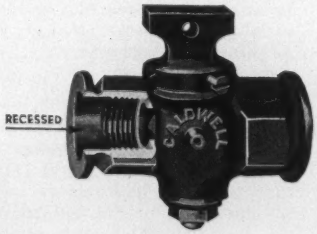


CALDWELL

Our INVERTED KEY cocks have EXTRA HEAVY bodies SOLID PLUGS and FULL SIZED Round Water-way. Notice that the BI-PASS is so constructed that No Sand, Grit or Sediment can come in contact with the bearing surface of the plug.

These Cocks furnished with Non Breakable, Non Corrosive Manganese Bronze Tee Heads.

Guaranteed to turn easy under all pressures and conditions.



EXTRA HEAVY RECESSED NEWPORT CURB COCKS

Recessing permits the threads on the service pipe to be entirely covered. This retards CORROSIVE action and gives greater strength at the weakest point on the service.

"Boxfindr"

GEO. A. CALDWELL CO.

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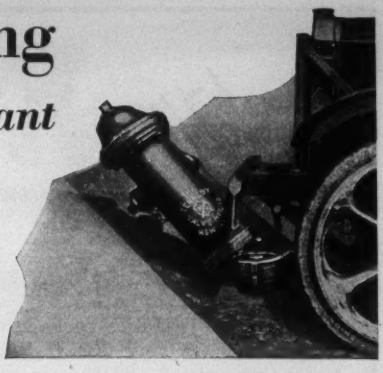
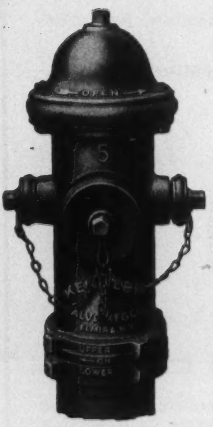
BOSTON, MASS.

"Pipefindr"

80% Saving

in fire hydrant collision repair cost





Send for Bulletin

IMPACTS that would demolish any other type of fire hydrant merely fracture an inexpensive Safety Breakable Section of the Kennedy SAFETOP Fire Hydrant without injury to the major parts of the hydrant. The water pressure in the main keeps the inlet valve tightly closed so that there is no danger of flooding. No excavating is necessary, nor need the water service in the vicinity of the broken hydrant be shut off while awaiting or making repairs.

The only parts that need be renewed cost $6.00. They can be replaced by one man, with standard tools, in less than half an hour.

This unique design therefore provides the important multiple benefits of (1) minimum interruption to fire hydrant service after breakage, (2) elimination of cost and trouble of excavation, (3) inconsequential cost of hydrant repairs, (4) security from suspension of water service, and (5) protection against serious property damage and personal injuries.

Any style of fire hydrant now installed can be replaced by a Kennedy SAFETOP Fire Hydrant at low cost and without removing the existing hydrant elbow.

The Kennedy Valve Mfg. Co., Elmira, N.Y.

KENNEDY

SAFETOP FIRE HYDRANT

REG. U.S. PAT. OFF.

EDDY

Valves and Hydrants

Distinctive Features of the EDDY Valves

ONLY three parts are moved by the Stem—the ball and the two gates. Each gate is hung from one of the trunnions on the ball. A convex surface at the base of each trunnion fits a concave surface on the back of the gate. This allows the gates to adjust themselves properly to their seats. . . . The gates, being free to revolve on the trunnions, do not always seat in the same position. Gates are center bearing and adjustable. They are forced to their seats with equal pressure at all points. There are two hooks on the ball on sizes 4-inch and larger, which loosely engage with the gates.

Distinctive Features of Our New Swivel Top Hydrants

THIS new hydrant has all the advantages of the popular EDDY fire hydrant, plus several additional features. . . . Nozzles are in a short flanged section of the standpipe, which may be unbolted and turned to different positions. . . . Should the standpipe be broken, only the casting below the swivel head need be replaced. . . . To raise the hydrant to conform to a new grading, simply insert a flanged extension piece below the swivelhead. No digging. To add a steamer nozzle at any time, it is only necessary to replace the swivel head with one having a steamer nozzle.

Besides valves and hydrants to meet the most exacting demands of waterworks service, the complete EDDY Line includes: valves for sewage disposal works; valves for steam, gas and oil; check valves, foot valves, plug valves, shear gates, indicator posts, etc. EDDY valves are made in three classes: Iron Body Bronze Mounted, All Bronze, and All Iron Valves.

Eddy Valve Co.

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LEAD PIPE

Used by leading WATER WORKS for over 50 years. If proper weight is used, combined with good workmanship, your FINAL COST is assured, as REPAIRS are unnecessary. LEAD PIPE is sufficiently ductile to conform to any sagging condition. There is no RUSTING of pipe or joints; no DISCOLORATION of water.

LEAD WOOL

Every Atom Pure Lead

For calking pipe joints under the most difficult conditions; for overhead joints or in wet places where the use of molten lead is not only impracticable but dangerous — LEAD WOOL may be used to advantage.

It makes an absolutely tight joint which will withstand the highest pressure, yet be sufficiently elastic to allow considerable sagging or settling of the pipe, without danger of leaks.

Compared with the poured joint, in this respect, the superiority of LEAD WOOL is apparent.

LEAD PIPE TIN-LINED LEAD PIPE
PURE BLOCK TIN PIPE SOLDER
DUTCH BOY WHITE LEAD & RED LEAD

Highest Quality Soft Virgin Omaha Pig Lead

NATIONAL-BOSTON LEAD CO.

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FOR CAST-IRON PIPE
FOR COLD WATER METERS

25c PER COPY

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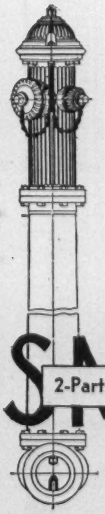


Minimum Trouble and Expense When Breaks Come

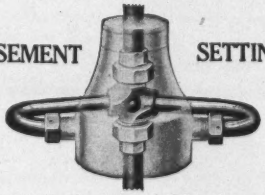
THE Smith Two-Part Standpipe Hydrant was designed to make the expense as small as possible when there is a break as the result, for instance, of careless auto truck driving.

The upper section will always break first. It can easily be renewed. And of course there can be no leakage of water because the main valve is of the compression type.

SMITH
2-Part Standpipe Hydrant

THE A. P. SMITH MFG. COMPANY
EAST ORANGE, N. J.

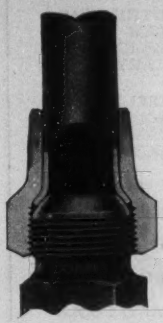
The
COPPERHORN
METER COUPLING
for BASEMENT SETTINGS



- ●1 **Meter set horizontally** at desired height in vertical pipe without ells, nipples or couplings.
- ●2 **All copper water way.** No rusting or corrosion. Freezing will not burst it.
- ●3 **Smooth oversize tubing** and sweeping bends, maximum flow.
- ●4 **Meter changes** do not disturb piping whether the meter is in or out.
- ●5 **On new services** it serves as a spacer to connect in the piping.
- ●6 **Provides a permanent** electrical ground connection.

May We Give You Further Information About the Copperhorn?

The FORD METER BOX COMPANY
Wabash, Indiana

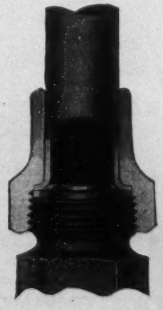


HAYS RADIUS SEAL JOINT

This type of joint was designed to meet the specific requirements of certain Water Departments and is available directly on all styles of Hays Copper Service fittings.

HAYS DOUBLE SEAL JOINT

This joint features a 2-faced pipe flare (45° + 90°) and a 2-faced machined seal (45° + 90°) which is by test the strongest flanged connection available. Available by Adapter on any Corporation Stop and directly on more than 400 styles and sizes of Hays Service and Plumbing fittings.



HAYS begins at the MAIN

Since 1869 Hays has built to the exacting requirements of the Water Works Industry. Tap the Main with a Hays Tapping Machine and follow through with dependable Hays Service Fittings for iron pipe, lead or copper. Hays Corporation Stops and Curb Stops are made in all styles and sizes. Write for Catalog.

USE THE HAYS COPPER SERVICE METHOD

Hays Adapts Copper to meet any Requirements

As a pioneer in the development of copper pipe services, Hays has popularized its use by making it easily adaptable to meet existing line equipment economically. Every community can have the advantage that copper pipe makes possible from Main to Curb to House with the Hays Copper Service Method. Let us have your problem.

HAYS MFG. CO.

ERIE, PA.

HAYS

PLUMBING BRASS
BATH FIXTURES
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GAS SERVICE GOODS
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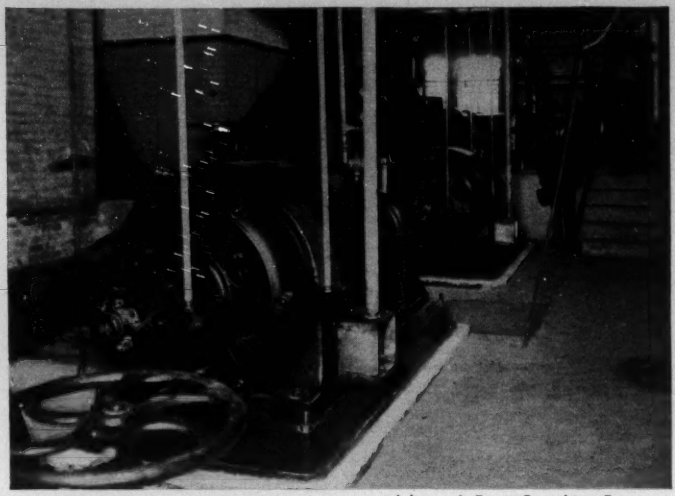

Johnson & Frost, Consulting Engineers

Investigate "5810"!

Lawrence, Mass., investigated—made a thorough analysis of pump construction—and "5810" won! Emphasis was placed on efficiency, undivided responsibility covering the equipment, and modern engineering design of both pumps and motors.

The above illustration shows the Fairbanks-Morse installation of two 8 in. Figure 5814 pumps driven by two 250 hp. synchronous motors now in operation at the Lawrence Water Works.

An interesting bulletin giving detailed and illustrated description of F-M "5810" will be mailed on request. Write Fairbanks, Morse & Co., 178 Atlantic Ave., Boston, Mass.

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PEERLESS PUMP COMPANY Massillon, Ohio	Turbine Type Centrifugal Deep Well Pumps for all services.
FULLER COMPANY Catasauqua, Pa.	Rotary Positive Displacement Compressors and Vacuum Pumps.

Furnished, Installed and Completed under One Guarantee and Responsibility "OURS."

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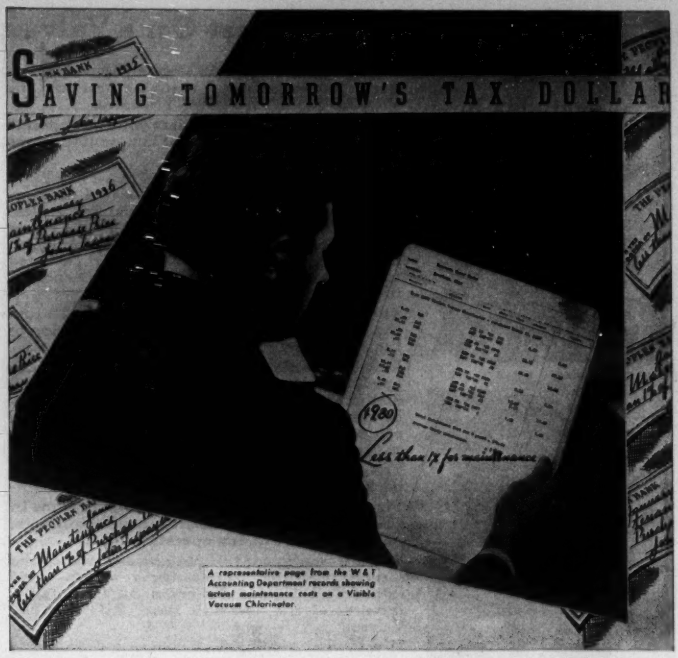
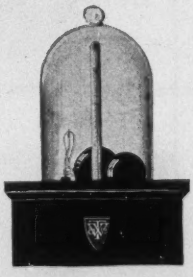


A representative page from the W & T Accounting Department records showing actual maintenance costs on a Visible Vacuum Chlorinator.

THE CHLORINATION DOLLAR

MUST BUY..MAINTENANCE ECONOMY



"HOW MUCH does it cost for upkeep?" is tomorrow's question. With a W&T Visible Vacuum Chlorinator the answer is ready—"Annual maintenance less than ONE PERCENT of the purchase price."

Analysis of repair costs of over 4,000 installations reports this figure. The reason?—Visible Vacuum design,—every working part in plain view under the glass bell jar. No hidden springs or diaphragms to fail, no small parts or orifices to clog, no interruption of Chlorination's vital task.

Ease your mind on chlorination by selecting W&T Visible Vacuum Chlorinators for dependable, accurate, trouble-free service, at minimum maintenance expense.

Through years of service tomorrow's taxpayers will applaud your choice of low maintenance equipment.

Technical publications 38, 157 and 158 describe W & T Visible Vacuum Chlorinators. Ask for your copies.

WALLACE & TIERNAN CO. Inc.
Manufacturers of Chlorine and Ammonia Control Apparatus
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SLUDGE LINES
SEWAGE DISPOSAL
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WORLD'S BEST AUTOMATIC Valves

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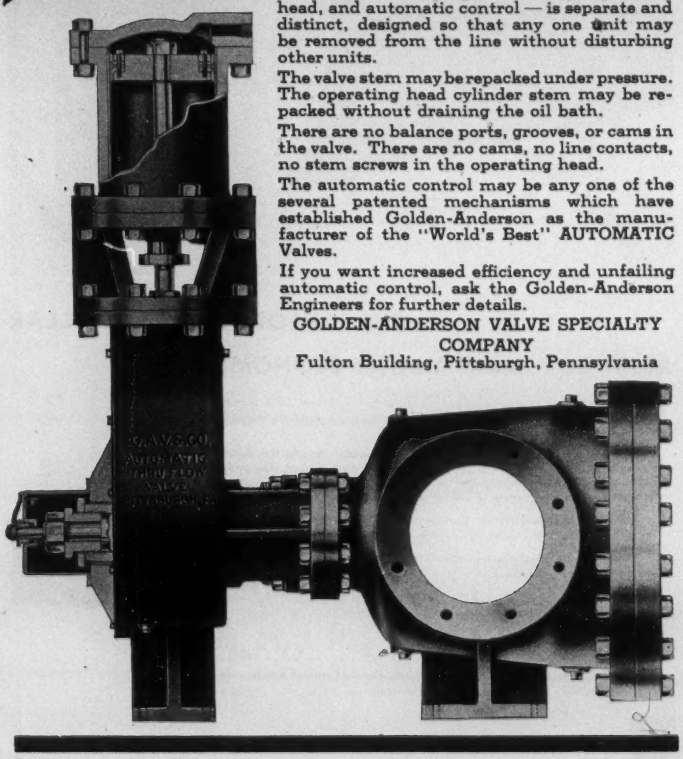

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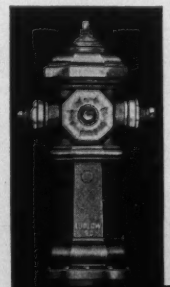

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- ✓ Surge and water hammer eliminated.
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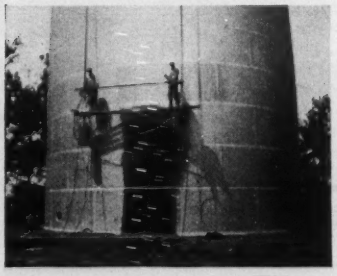

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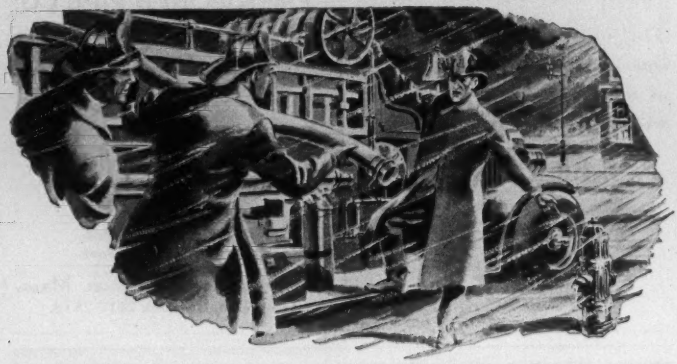
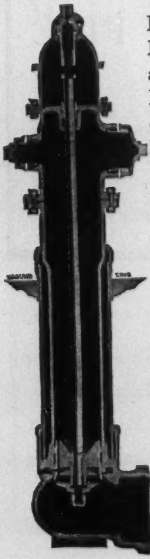
Sleet Didn't Stop Us,

AND IT WON'T STOP THAT MATHEWS"





He's right. Sleet won't stop a Mathews Hydrant. It can rain and freeze an inch thick, but Mathews Hydrants open as easily as in June. They're built for this emergency.

Winter can't freeze up a Mathews threads because they don't get wet. Winter can't freeze a Mathews standpipe because it drains fast. Winter can't heave a Mathews loose because of its sliding protection case. Buy Mathews Hydrants. They're built for winter-time emergencies.

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See that shield-operating nut? It sheds outside water like a gable roof. And below the operating threads is a stuffing box protecting them from inside water. Between the two, there's never any moisture. The threads can't freeze because they don't get wet.

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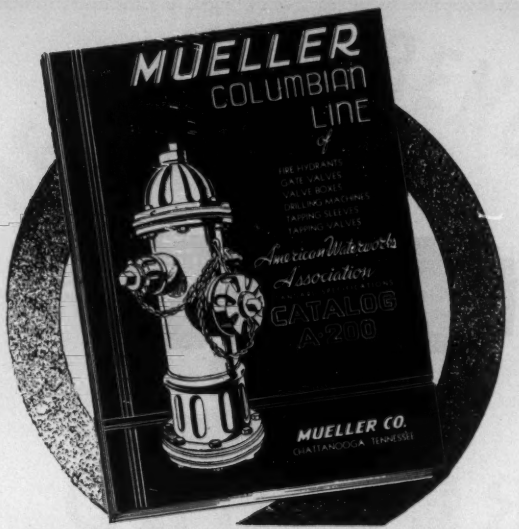

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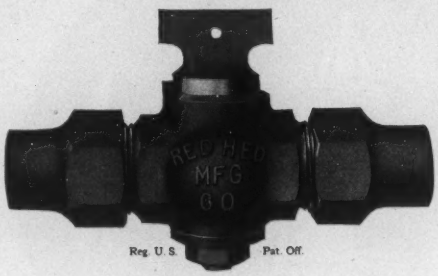

Fig. 415

RED HED

HIGH GRADE

BRASS GOODS

FOR

WATER WORKS

RED HED MFG. CO.

368 CONGRESS STREET BOSTON, MASS.

RESERVE STRENGTH

Fig. 883
Double Disc
Parallel Seat

—*makes ordinary duty easy for a Jenkins*

STRENGTH is emphasized in making Jenkins Iron Body Gate Valves for water works service. In both the Solid Wedge and the Double Disc Parallel Seat valves are many superior features that build up strength . . . that make a "Jenkins" capable of handling ordinary duty with ease. The result is longer valve life and less maintenance. This great reserve strength also enables a "Jenkins" to carry-on even if extraordinary strains are encountered.

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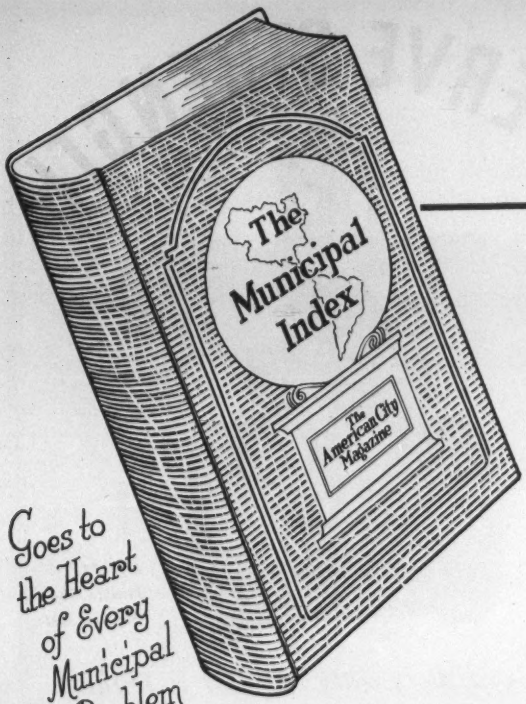
Jenkins Valves

BRONZE—IRON—STEEL SINCE 1864



Goes to the Heart of Every Municipal Problem

THE ANNUAL PURCHASING GUIDE for MUNICIPAL and WATER WORKS OFFICIALS

Published By

THE AMERICAN CITY MAGAZINE

470 Fourth Ave., New York

PROTECTION . . .

THE average person does not fully appreciate the efforts made by the personnel of the water plants for protecting the health of the community through the furnishing of a safe water.

In making water safe, oft' times it is done at the expense of palatability.

Most everyone will judge the safety of the water by its palatability, and frequently the overdosing of chlorine to make it safe, leaves such an unpalatable taste that often the consumer dangerously resorts to the use of so-called sparkling water from the "old dug well, spring," etc.

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From the Largest City in New England

BOSTON, MASSACHUSETTS

Recently endorsed the

UNION METER

By purchasing 2800 King Meters

UNION WATER METER COMPANY

Established 1860

WORCESTER, MASSACHUSETTS

UNDER the surface—in seawater and in the ground—cast iron resists the attack of corrosive elements more effectively than any other ferrous metal practicable for the purpose, with or without linings. Special linings are in most cases unnecessary. If abnormally active waters are to be transported, we furnish U. S. pit cast pipe, or Super-de Lavaud centrifugally cast *chill-free* pipe, lined in accordance with the results of years of research and experience. Our Research Headquarters at Burlington, generally considered one of the finest foundry laboratories in the world, and our technical staffs, have made important contributions to the design and production of cast iron and alloy cast iron pipe for super-corrosive conditions. U. S. Pipe & Foundry Co., Burlington, New Jersey.

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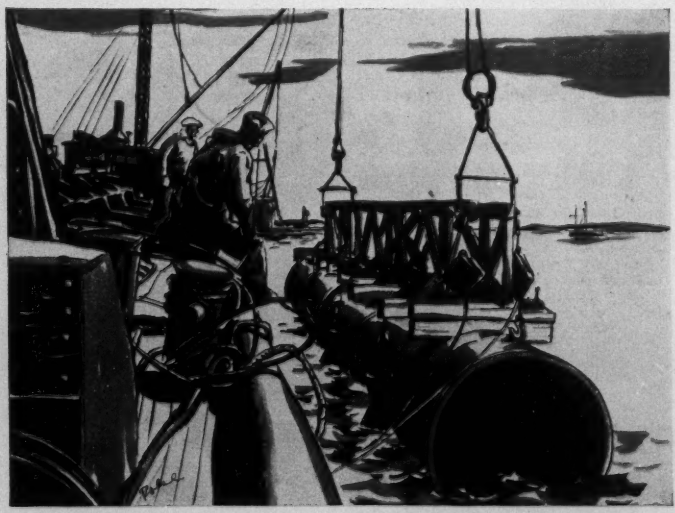

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